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THE FIELD ARTILLERY SCHOOL

Department of Materiel

1938-1939

INSTRUCTION MEMORANDUM

CONSTRUCTION OF FIELD ARTILLERY MATERIEL

For use in Resident Instruction at the
Field Artillery School only.

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ILLUSTRATIONS

CONSTRUCTION OF FIELD ARTILLERY MATERIEL

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1. **General.**—This memorandum will be devoted to a general discussion of the construction of field artillery materiel. The scope of the discussion is sufficient to provide a background for the future study of all field artillery officers. The purpose, construction, use, advantages, and disadvantages of each component part will be separately discussed. Details of construction of interest only to the Ordnance Department, computations of stresses and strains, and the like are beyond the scope of this text. From the artilleryman's viewpoint, the technique used by the manufacturer is secondary to the results obtained in meeting a proper balance of the essential characteristics of a piece.

2. **Essential characteristics of a piece.**

a. All the essential characteristics of a piece are interdependent, so that the piece as a whole is a compromise with respect to the desirable characteristics for that particular weapon. The best combination of characteristics is determined by consideration of the mission of the piece in battle.

b. The principal characteristics desired in field artillery weapons are:

(1) *Long range.*—The ability to reach far into the enemy territory from a position sufficiently in rear of the friendly infantry to afford protection to the piece.

(2) *Great fire power.*—The ability to fire, within a short space of time, sufficient quantities of projectiles of the proper type to accomplish the mission for which the piece is intended.

(3) *High mobility.*—The ability to move, both strategically

and tactically, over varied terrain so as to insure the presence of the materiel and ammunition at the right place at the right time.

(4) *Stability.*—Steadiness of the carriage under shock of discharge, to insure accuracy and speed in firing.

(5) *Ruggedness.*—The capacity of the weapon under all conditions to move and to fire without incurring breakdowns and malfunctions which might put the piece out of action.

(6) *Simplicity.*—The freedom from complexity which contributes to ruggedness, simplifies the training of personnel, and reduces the time and cost of manufacture.

(7) *Accuracy.*—The ability of a weapon to complete the execution of a mission with the minimum expenditure of ammunition and time. The indication of accuracy in firing is the amount of the probable error.

(8) *Wide traverse.*—The ability of the gun to move with respect to the carriage, through large horizontal angles.

(9) *Flexible elevation.*—The ability to rapidly change the elevation of the gun through large vertical angles in order to take advantage of the proper trajectory for the particular mission.

3. **Components of the piece.**—A modern artillery weapon consists of some of or all the following components:

a. *Gun or howitzer assembly.*

(1) Barrel or tube assembly.

(2) Breech mechanism.

b. *Carriage.*

(1) Recoil mechanism.

(2) Cradle.

(3) Top carriage.

(4) Bottom carriage.

(5) Elevating mechanism.

(6) Traversing mechanism.

(7) Axle.

(8) Trail.

(9) Wheels.

(10) Brakes.

(11) Shield.

c. Accessories.

(1) Sights.

(2) Gunner's quadrant.

(3) Fuze setter.

(4) Miscellaneous tools and accessories.

GUN OR HOWITZER ASSEMBLY

BARREL OR TUBE ASSEMBLY

4. **General.**—The terms *barrel* and *tube* are used interchangeably throughout this text, their use depending on the nomenclature as listed in the standard nomenclature list (SNL) of the weapon under discussion. The tube assembly consists of the tube and various surrounding and attached parts for strengthening it, for holding the breech mechanism, and for securing the tube assembly to the carriage.

a. The *tube* is the inner cylinder of the barrel or tube assembly. It contains the rifled bore, except where a removable liner is used. The interior of the tube is divided into six parts, from breech to muzzle as follows (FIG. 1):

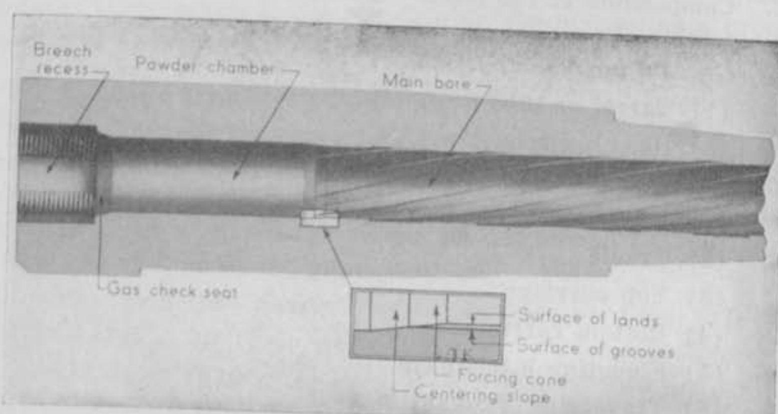


FIGURE 1.—Parts of the bore.

(1) *Breech recess.*—The breech recess is the space formed by the interior of the rear extension of the jacket or tube proper which is prepared to receive the breechblock.

(2) *Gas-check seat.*—In guns which use separate-loading ammunition, the rear portion of the bore is tapered to form a gas-check seat to receive the gas-check pad of the breechblock and to insure proper obturation when firing. In the bore of the guns using fixed or semifixed ammunition, this seat is not found, as obturation is accomplished by means of the cartridge case (Par. 18).

(3) *Powder chamber.*—The powder chamber is that portion of the bore which is designed to hold the cartridge case or, in case of separate loading ammunition, to hold the powder charge.

(4) *Centering slope.*—The centering slope is the tapered forward portion of the powder chamber. It is designed to cause the projectile, during the loading operation, to center itself in the bore.

(5) *Forcing cone.*—The forcing cone is the rear portion of the main bore. It is formed by tapering the rear of the lands. Its function is to receive and seat properly the rotating band of the projectile.

(6) *Main bore.*—The main bore includes all that portion forward of the centering slope, that is, the entire rifled portion of the bore.

b. In the construction of the tube assembly, consideration must be given to each of the following:

(1) Methods of construction.

(2) Methods of stressing.

(3) Rifling.

(4) Erosion.

5. Methods of construction.

a. The methods of construction of the tube assembly are of interest to the field artilleryman chiefly from the standpoint of completing his background. All modern tubes are made from alloy steel forgings or centrifugal castings.

b. Forgings for gun tubes are made by hot-working a steel ingot of the proper chemical analysis to the desired rough size. In order to insure removal of flaws, about 35 percent of the original ingot is discarded by cutting off the ends of the finished forg-

ing. By a series of heat-treatment and machining operations the tube is made from the finished forging.

c. Centrifugal castings are made by pouring molten steel of the proper chemical analysis into a horizontal container which is rotating at a speed of from 800 to 1500 revolutions per minute. The casting is then heat-treated and machined to its final finish. The following advantages are claimed for centrifugal castings:

(1) Decreased weight for a given strength.
(2) Decreased time and cost of production.
(3) Smaller amount of raw materials required.
(4) Reduced plant and equipment requirements.
(5) Better steel metallurgically.

6. Methods of stressing.

a. When the piece is fired, the tube is subjected to certain stresses as follows (Fig. 2):

(1) *Tangential stress,* compression or tension in a plane perpendicular to the axis of the bore and in directions perpendicular to the radii of the bore.

(2) *Radial stress,* compression in the direction of the radii of the bore.

(3) *Longitudinal stress,* tension in the direction of the axis of the bore.

b. The tangential and radial stresses tend to burst the gun. The longitudinal stress tends to pull the gun apart in the direction of its length. For a given cross section of the gun, the longitudinal stress is substantially uniform throughout the entire section. Tangential and radial stresses, however, vary with the distance from the bore; both are much greater at the bore than at the exterior of the gun.

c. Modern guns are so designed and constructed as to utilize all the metal to resist the tangential and radial stresses and to furnish a factor of safety. The gun is then sufficiently strong to resist the longitudinal stresses. This result is obtained by placing the inner layers in a state of initial compression and the outer layers in a state of initial tension, within the elastic limits of the metal. The pressure of firing is absorbed first by relieving the initial compression of the inner layers and then by sujecting

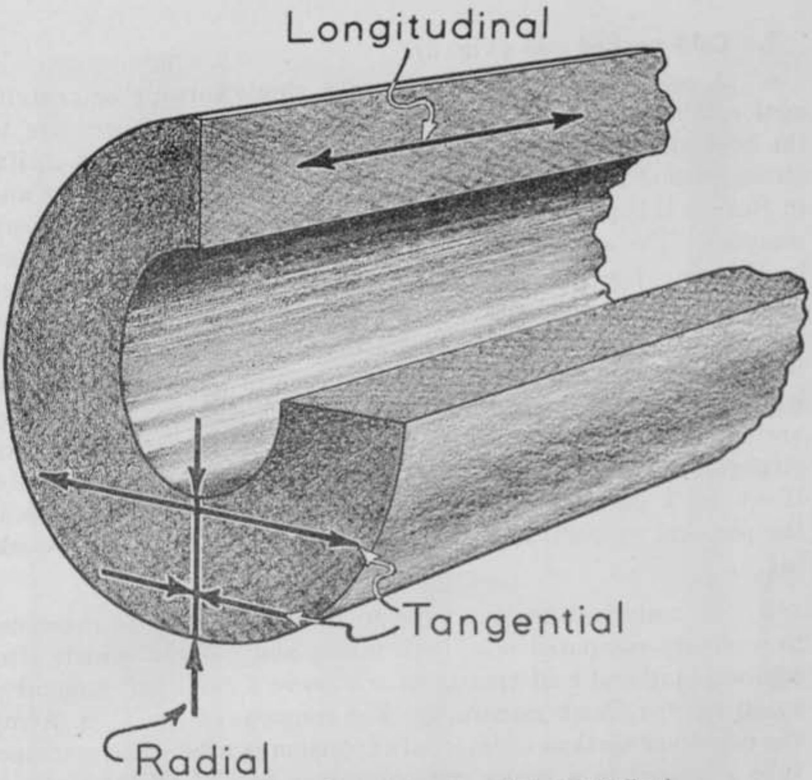


FIGURE 2.—Directions of stresses when gun is fired.

them to tangential tension and radial compression within the limits of safe strength.

d. The tangential and radial stresses vary along the length of the tube. At any one cross section they are dependent upon the pressure at that section. Therefore, in order to conserve metal and weight, the gun is varied in strength along its length, according to the pressure curve, being strongest for a certain distance from the breech and weakest at the muzzle. For this purpose the tube is reinforced as necessary at the various points of its length. Since the metal at the muzzle receives support from one side only, the wall section at that point is usually thickened to make its strength equal to that of the adjoining section.

e. According to the methods used in setting up the initial stresses, guns are referred to as *cold-worked, built-up,* or *wire-wrapped.*

7. Cold-worked gun (Fig. 3).

a. A *cold-worked* gun is made of a single forging or centrifugal casting in which, by mechanically applying a pressure to the bore of the tube, the inner fibers are placed under an intital stress beyond the elastic limit of the metal. In this country and in Europe this process is used in the construction of most modern weapons. The synonymous term auto-frettage is in general use in Europe. The internal pressure used in manufacture is such as to give the inner layers a permanent set, while the outer layers are not strained beyond their elastic limit. When the pressure is released, the outer layers tend to return to their original state, while the inner layers do not. The result is that the inner layers are compressed by the outer layers. By this method the elastic strength of a simple cylinder may be approximately doubled. However, a part of this increase may be due to the increase in the physical properties of the metal as a result of the cold-working.

b. In manufacture, the tube to be cold-worked is machined to a closely computed size, both inside and outside, which after cold-working and heat treatment will leave a sufficient amount of metal for the finish machining. For weapons of the U. S. Army, the *container method* of internal expansion is used. The machined tube is placed in a heavy steel container having an interior surface corresponding to the exterior surface of the tube. The ends of the tube are securely closed and hydraulic pressure sufficient to force the entire tube tightly against the container is then applied to the interior of the tube. This pressure causes the inside fibers to be stretched beyond their elastic limit, so that upon release of the pressure the inside fibers are placed in compression. The tube is then heat-treated and finish machined.

c. The process of cold-working as applied on the latest model guns and howitzers permits the use of the so-called *mono-block* type of tube assembly. In this type the tube assembly consists of a single cold-worked tube which is threaded at its rear end to receive the breech ring.

d. The advantages of this method are:

(1) The tube will withstand higher pressures than will one of equal weight stressed by other methods.

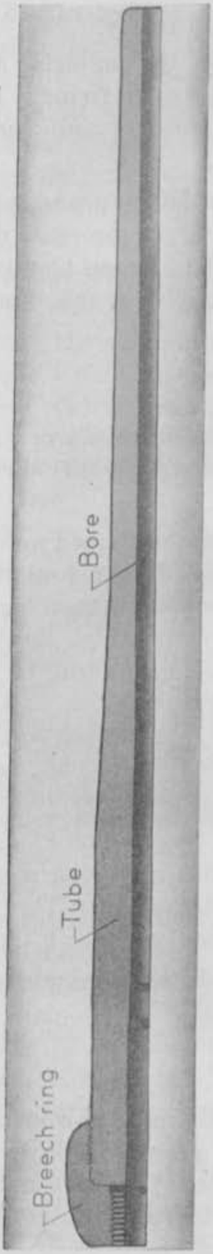


FIGURE 3.—Cold-worked gun, mono-block type.

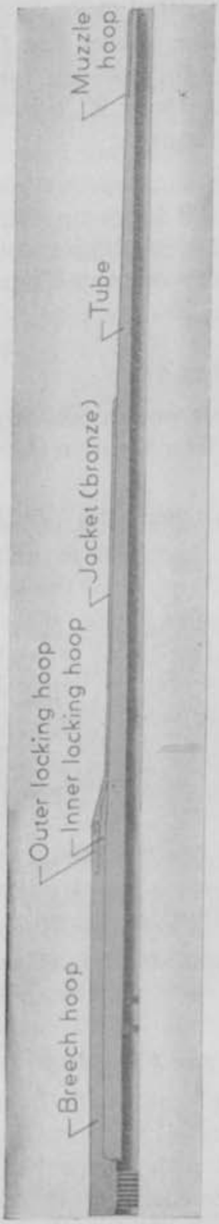


FIGURE 4.—Built-up gun.

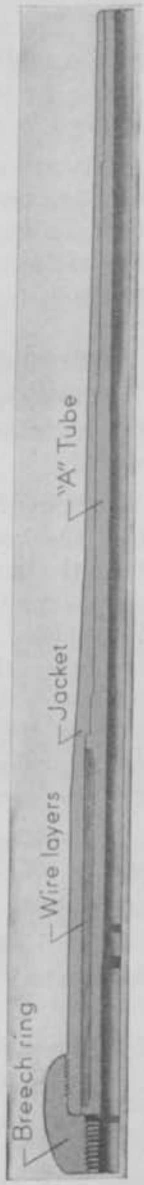


FIGURE 5.—Wire-wrapped gun.

(2) It is manufactured more cheaply and faster.

(3) The processing shows any flaws in the material and serves to establish a safe pressure for the tube in firing. The safe firing pressure is about 95 percent of the hydraulic pressure applied in manufacture.

e. This process can be used to replace the built-up and wire-wrapped processes on all tubes up to 8 inches. At present, it is standard for all light and medium cannon. The 75-mm. howitzer, M3A1, and the 105-mm. howitzer, M2, are examples of this type of construction.

8. Built-up gun (Fig. 4).

a. A built-up gun is one in which the tube is reinforced and placed under initial compression by means of *hoops* shrunk around it.

b. In manufacture, the tube is accurately machined on the outside; the hoop is machined to an interior diameter slightly less than the outside diameter of the tube; the hoop is then heated so as to expand it sufficiently, placed over the tube, and the whole is cooled. The final heat treatment and machining is performed after the assembly is completed. The number and arrangement of the hoops vary. They are named according to their position on the tube; as, *breech hoop, muzzle hoop,* etc. *Locking hoops* are used to join adjacent hoops in order to avoid longitudinal weakness.

c. A built-up gun has the advantage of not requiring a large expensive container, as is required for cold-working. The process is simpler than that for the wire-wrapped gun.

d. The 75-mm. gun, M1897 (French), is an example of a built-up gun.

9. Wire-wrapped gun (Fig. 5).

a. A wire-wrapped gun is one in which the tube is reinforced and placed under initial compression by successive layers of wire wound about it with the proper tension. The wire may be wound with either constant or increasing tension, the constant tension being used more frequently.

b. In the construction, wire of square cross section is wrapped in layers around the machined tube. The number of layers of wire is varied along the tube, according to the strength required at each point. Since the wire wrapping affords no longitudinal strength and that of the tube is limited, a jacket is placed over the wire, with or without shrinkage. The rear of the jacket houses the breech mechanism, or it receives a *breech ring* for that purpose. The pull of the breech mechanism tends to cause slippage of the jacket to the rear over the wire wrapping. This is prevented by suitable shoulders on the jacket and on the tube.

c. The advantages of the wire-wrapped construction as compared with the built-up are:

(1) Economy.

(2) Flaws in the material can be readily detected.

(3) Full advantage is made of the high tensile strength of wire.

d. The 75-mm. gun, M1917 (British), is an example of a wire-wrapped gun.

10. Rifling.

a. *Rifling* consists of a number of spiral grooves in the surface of the bore. The raised portions between the grooves are the *lands*. The purpose of rifling is to rotate the projectile about its axis, in order to give it stability in flight. The soft copper *rotating band* of the projectile is forced into the grooves by the powder gases, thus causing the projectile to spin as it passes through the bore.

b. The twist of the rifling is the inclination of the grooves to the axis of the bore, and it is expressed in terms of caliber. Thus, a twist of one turn in 25 calibers means that the projectile makes one revolution in moving along the bore for a distance of 25 times its diameter. The twist is no greater than is necessary to insure stable flight, because a large twist tends to *strip* the rotating band from the projectile. The longer the projectile, the greater is the twist required. Twist is designated as *right* or *left* hand and as *uniform* or *increasing*. The present tendency in our service is to use uniform right-hand twist. Right-hand twist causes the projectile to rotate in a clockwise direction and to drift to the right in flight. An increasing twist lessens the danger of strip-

ping the rotating band and reduces slightly the maximum pressure in the gun. A uniform twist is simpler to manufacture and, owing to the constant pitch of the grooves cut in the rotating band, results in less friction.

c. The number and depth of the grooves vary in different guns. Usually there are between six and nine grooves per inch of caliber. The general tendency is to increase both the depth and number of grooves.

11. Erosion.

a. Erosion is the gradual wear of the bore during firing. The rate of erosion determines the accuracy life of the tube. Erosion is caused by one or both of the following:

(1) The action of the hot gases moving at high velocity in contact with the bore and possibly escaping past the rotating band.

(2) The formation of a brittle compound as a result of the absorption of chemicals by the steel surface of the bore. The powder gases break and wear away this brittle compound.

b. Erosion increases as the muzzle velocity of the projectile increases, and with extremely high velocities is very great. It is greatest at the origin of rifling, at the forcing cone. As erosion progresses, the forcing cone is advanced, the advancement resulting in an increased size of the powder chamber. This change causes a loss of range and accuracy.

12. Removable liners.—A removable liner is a tube containing a complete bore which is inserted and locked on the inside of the tube proper. It is designed, primarily, to permit the replacement in the field of that portion of the gun tube which is subject to the greatest amount of erosion, particularly for high-velocity guns. The tube proper and liner are built and cold-worked separately. Since the two parts require pieces of metal of about equal original size and both parts have to be separately processed, the saving is not so great as would be expected. The present trend is to build mono-block tubes and to replace these as they are worn out, this method saving almost one half in the cost and time required for construction of the removable-liner type of tube assembly. Removable liners are not used on any field artillery guns at the present time.

13. Summary.—The complete characteristics of a tube assembly include:

a. Length expressed in calibers.

b. Diameter between lands.

c. Forged or centrifugally cast.

d. Method of stressing:

(1) Cold-worked (may be mono-block).

(2) Built-up.

(3) Wire-wrapped.

e. Rifling:

(1) Twist:

(a) Uniform or increasing, with amount.

(b) Right or left hand.

(2) Number of grooves.

(3) Depth and width of grooves.

BREECH MECHANISMS

14. General.

a. The breech mechanism is a mechanical device which serves to close securely the rear of the tube for firing, to assist in preventing the escape of the powder gases to the rear, to afford a means of loading the gun at the rear, and to house the firing mechanism. It consists of the *breech-block*, the *obturating device* (if the ammunition is separate-loading), the *firing mechanism*, the *operating mechanism*, and the *safety devices*.

b. According to the form of the breechblock, the three types of breech mechanisms are the *interrupted-screw type*, the *sliding-wedge type*, and the *eccentric-screw* (Nordenfeld) *type*.

c. The methods of obturation in general use are the use of cartridge cases and the use of the *De Bange obturator*. There are other means, such as the "Broadwell Ring" and "Freyre obturator," but their use has not been wide either in this country or abroad.

d. The types of firing mechanisms in use are the *continuous-pull type* and the *percussion-hammer type*.

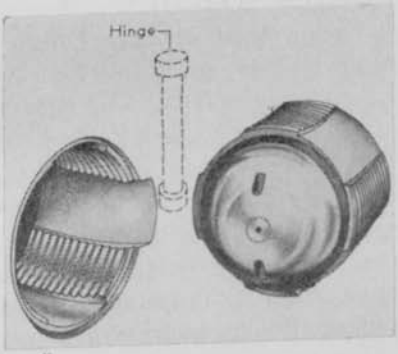
15. Interrupted-screw type (Fig. 6 ①).

a. The interrupted-screw (or slotted-screw) type of breech mechanism is one in which both the block and the breech recess are threaded, sectors of the threads, running from front to rear, being removed to facilitate insertion and withdrawal of the block. The type most widely used is cylindrical in shape, has two or more plain sectors, and has the exterior diameters of all threads on the block equal. The threads are so designed that under the force of the powder pressure friction will prevent the block from rotating.

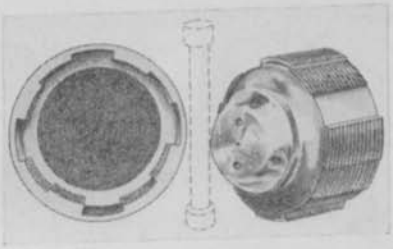
b. The breechblock is operated by inserting the block into the recess with the threaded sectors of the block passing through the plain sector of the recess. The block is then turned so that its threaded sector engages the threaded sector of the breech recess in order to close the breech. The arc through which the block must be turned to close the breech is comparatively small, decreasing as the number of sectors into which the block is divided are increased. With this type of block it should be noted that the maximum threaded area cannot exceed one half of the total surface of the block.

c. Two variations of this type of block have been made which permit an increase in the threaded area without an increase in the size of the block. One variation is known as the *Welin stepped-thread block* (Fig. 6 ②). In this block the threaded sectors are built in two or more steps, the blank sectors being of less diameter than any threaded sector. Likewise, the breech recess is threaded in steps, the blank sectors being of larger diameter than any threaded sector. By this means the threaded area may include a much larger portion of the surface of the block, and, to close the breech, less rotation of the block may be required. The other variation is known as the *Bofors breech mechanism* (Fig. 6 ③). The block and breech recess are very wide at the rear, the bearing surface being thereby increased. Since the block is ogival in shape, only a very small retraction to the rear is required before the block can be swung open.

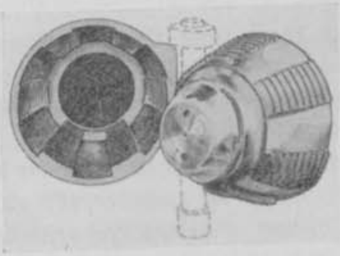
d. The interrupted-screw type has the advantage of being lighter than other types of breech mechanisms; therefore, it is particularly adapted to heavy artillery, where it is chiefly used.



① Simple interrupted-screw type.



② Welin stepped-thread type.



③ Befors ogival type.

FIGURE 6.—Interrupted-screw types of breechblocks.

It also has the advantage over all other types in that all-around support of the breechblock is obtained. It can be used with all types of ammunition.

e. Representative examples of the interrupted-screw type of mechanism are found on the 75-mm. gun, M1917 (British), the 155-mm. howitzer, M1918, and the 155-mm. gun, M1918 (GPF).

16. Sliding-wedge type (Fig. 7).

a. The sliding-wedge type of breechblock is a rectangular wedge-shaped block which is seated in a slot cut in the breech of the gun at right angles to the bore. The slot may be either horizontal or vertical. Where the sliding block operates vertically, it is known as the *drop-block* type. Where it operates horizontally, it is known as the *horizontal sliding-wedge* type.

b. The sliding-wedge type of breechblock is so constructed that when the breech is closed the cartridge case is forced home. This is accomplished either by tapering the rear face of the block or by having the block slide on inclined grooves in a recess across the breech.

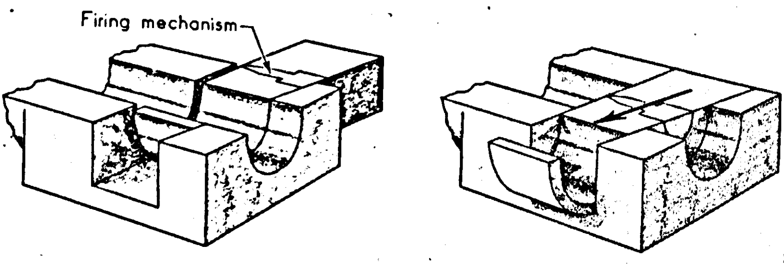


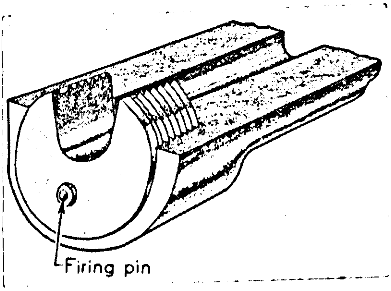
FIGURE 7.—Sliding-wedge breechblock.

c. This type of block has the advantage of being readily adapted to semiautomatic operation. When so adapted, the breech is closed by inserting the round of ammunition. In some weapons, the breech may be opened automatically by counterrecoil. It is a type of mechanism very advantageous for weapons which have a high rate of fire, such as antiaircraft guns. It is applicable only to guns firing fixed or semifixed ammunition.

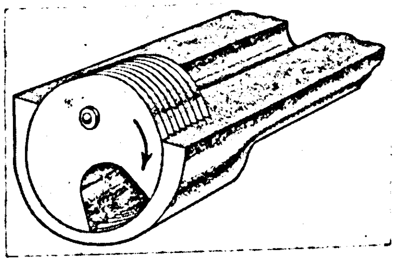
d. The sliding-wedge type of mechanism is used on the 75-mm. gun, M1916 (American) and the 75-mm. and the 105-mm. howitzers.

17. Eccentric-screw type (Fig. 8).

a. The eccentric-screw, or Nordenfelt, type of breechblock is cylindrical in form and is threaded on its outer surface to screw into the breech recess. The block is made much larger than the chamber of the gun, and the axis of the block is offset from the



Breech open.



Breech closed.

FIGURE 8.—Eccentric-screw breechblock.

axis of the bore. The block remains in the breech recess during the operations of opening and closing the breech.

b. The breech is opened by rotating the block about its axis slightly less than one half of a revolution, so that a U-shaped opening at one side of the center is brought into axial alinement with the bore. The U-shaped opening is large enough to receive the ammunition and thus forms a loading hole.

c. The advantages of this type are that the mechanism, being all enclosed, is not liable to damage and that rapid operation is permitted. It is applicable only to guns firing fixed or semifixed ammunition. It is too heavy for large guns.

d. The eccentric-screw type of mechanism is used on the 75-mm. gun, M1897 (French), and the 37-mm. gun, M1916.

18. Obturation by use of a cartridge case.

a. An obturating device is one which seals the breech against the escape of powder gases when the gun is fired. In all cases where fixed or semifixed ammunition is used the obturation is accomplished by means of the cartridge case.

b. When the cartridge case is inserted, it fits the powder chamber, but not tightly enough to bind. The base of the cartridge case is in close contact with the face of the breechblock, rupture of cases being thereby prevented. When the piece is fired the powder gases expand the case, pushing it firmly against the walls of the powder chamber, so that gases cannot escape around the lips of the case. When the powder pressure is released, the cartridge case springs out from the wall sufficiently

to enable its removal. Cartridge cases should be resized before being again used.

c. The advantages of obturation by cartridge cases are, first, simplicity of the breech mechanism; second, that it permits the use of any type breechblock; and third, that it assists in increasing the rate of fire.

d. Examples of obturation by cartridge cases are found on all light weapons; such as, the 75-mm. guns, M1897, M1916, and M1917.

19. De Bange obturator (Fig. 9).

a. The De Bange obturator is a device for preventing the escape of the powder gases through the breech of guns using separate-loading ammunition. It is applicable only to the interrupted-screw type of breech mechanism. It consists of a steel mushroom head mounted on the front face of the breechblock. Between the mushroom head and the breechblock is a heat-resisting plastic pad of asbestos and nonfluid oils, surrounded by three

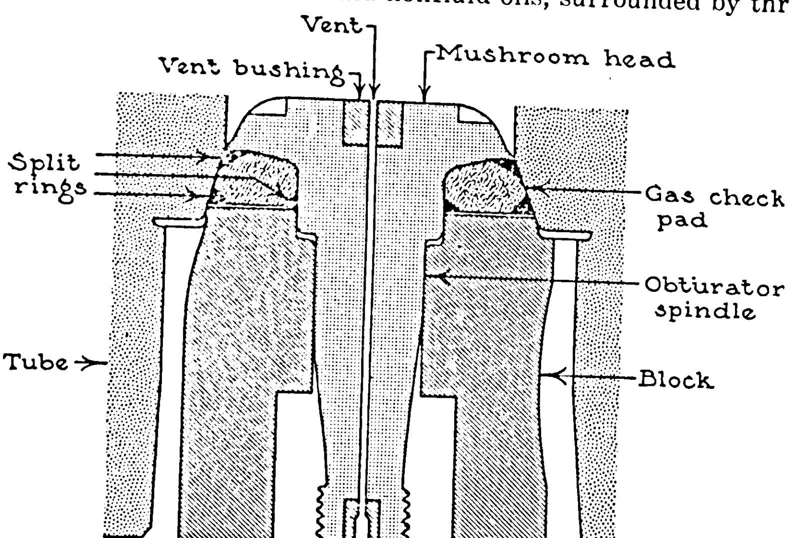


FIGURE 9.—De Bange plastic obturator.

steel split rings, two of which are ground to seat accurately in the breech recess.

b. When the gun is fired, the gas pressure forces the mushroom head slightly to the rear. This movement compresses the

plastic pad and forces it and two steel rings tightly against the recess, thus sealing the breech against the passage of gas. The smaller split ring surrounding the spindle serves to prevent escape of the pad composition between the block and the spindle.

c. This device is universally used on all guns which use separate-loading ammunition, except the older Krupp models which use a cartridge case. An example of this type is found on the 155-mm. gun, M1918.

20. Continuous-pull firing mechanism (Fig. 10 ①).

a. A continuous-pull type of firing mechanism is one in which the pull of the lanyard cocks and releases a spring-actuated firing pin, the firing pin reassuming its normal position upon release of the lanyard. The type of mechanism in general use in this country, the *firing lock, M13,* will be described in detail in this paragraph. This mechanism is assembled into a *firing case.* The complete assembly is installed in a central hole in the breechblock and is retained therein by sector lugs on its exterior engaging with lugs on the block. The case is prevented from rotating out of engagement by the trigger shaft which enters and operates it. The firing-pin holder, holder sleeve, firing pin, firing-pin bushing, sear, sear spring, and trigger fork are all contained in the firing case.

b. The firing-pin holder has a cylindrical head which slides in the bore of the firing case and a flattened stem which passes to the rear through the firing spring, through the firing-pin holder sleeve, and between the prongs of the trigger fork. The firing pin is loosely secured to the front end of the firing-pin holder by means of a bushing and a cotter pin, forming with the holder an assembly. The sear rests in a groove below the center of the firing case. The rear end of the sear rotates about the trigger shaft, and the forward end is pushed upward into contact with the firing-pin assembly through the action of the sear spring. A notch at the front end of the sear engages the head of the firing-pin holder in the readiness position. The upper surface of the sear, to the rear of the notch, has a cam surface upon which the firing-pin holder sleeve rides. This sleeve encircles the firing spring and has an enlarged portion at the top upon which the extreme end of the trigger fork presses. The trigger

fork is a Y-shaped piece, the ends of the Y contacting the sleeve, the lower portion of the Y straddling and connecting the T-head on the rear end of the firing-pin holder, and the lower leg having a square hole through which the trigger shaft passes.

c. Firing is accomplished by a sharp rearward pull on the lanyard. However, the force of the pull has no effect on the force of the blow on the primer. As the trigger shaft is rotated by the lanyard, the trigger fork forces the firing-pin holder sleeve forward, this action compressing the firing spring. When the desired amount of compression is reached, the sleeve cams the sear downward by means of its contact on the upper cam surface. This releases the firing-pin holder, which flies forward under pressure of the spring, and the firing-pin strikes the primer. Upon release of the lanyard the firing lock parts return automatically to their position at rest (the readiness position) in the following manner. The firing spring presses forward on the firing-pin holder and rearward on the sleeve. The ears at the rear of the firing-pin holder thus press forward and the upper rear of the sleeve pushes rearward on the trigger fork. These efforts are equal in strength, but that on the sleeve acts against a longer lever arm, overcomes the pull of the firing-pin holder, and rotates the trigger fork about the axis of the trigger shaft, drawing the firing-pin holder back until its head again is engaged with the sear.

d. The advantages of the continuous-pull type of mechanism are:

(1) The blow of the firing pin is constant under all conditions.

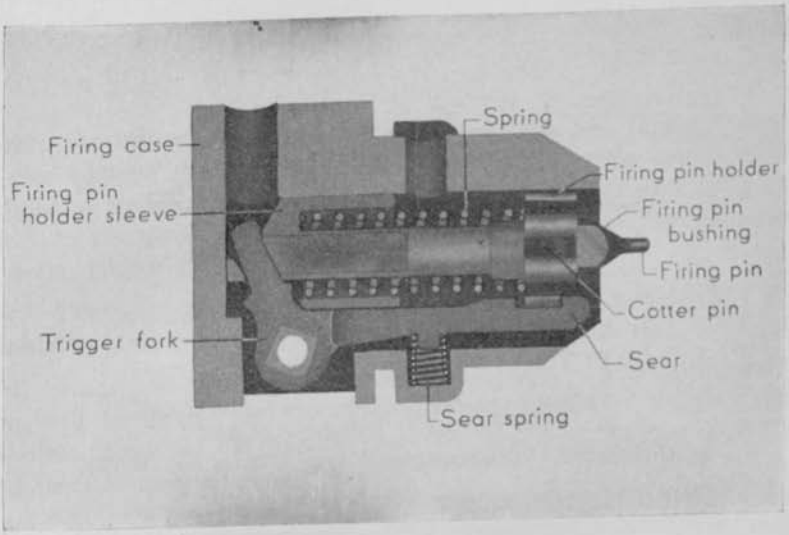
(2) The action is rapid.

(3) All vital parts are enclosed.

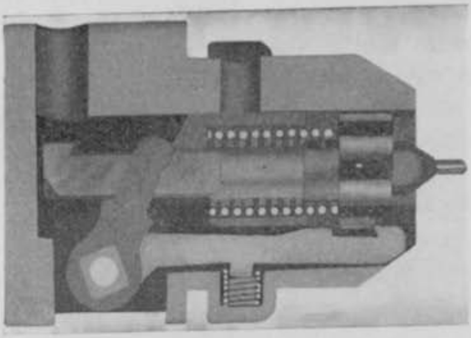
e. The firing lock, M13, is used on the 75-mm. howitzer, M1, M3, and M3A1, and 105-mm. howitzers. Similar mechanisms will be found on the 75-mm. guns, M1916 and M1917.

21. Percussion-hammer firing mechanism (Fig. 10 ②).

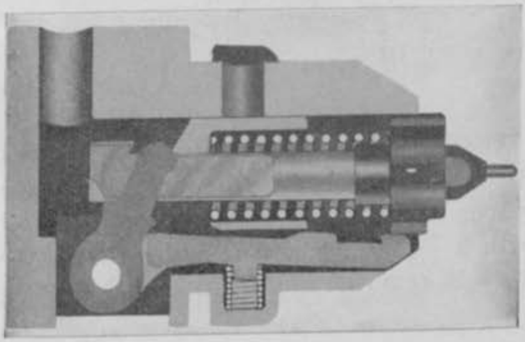
a. A percussion-hammer type of firing mechanism is one in which a hammer strikes the firing-pin and fires the piece. The hammer may be actuated by a spring which is released when



(*a*) At rest, cocked.



(*b*) At moment of tripping the sear.



(*c*) At moment of striking the primer.
⊙ Continuous-pull type (firing lock M-13).
FIGURE 10.—Firing mechanisms.

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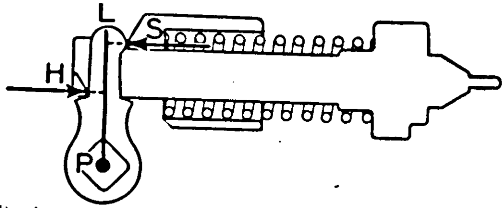
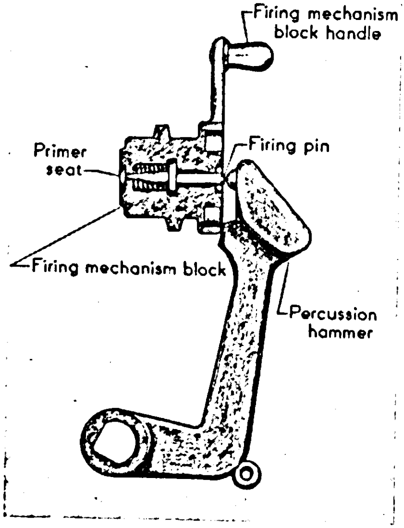


(*d*) Automatic cocking.
P: Trigger fork pivot.
L: Lever arm.
S: Force exerted by firing pin holder sleeve.
H: Force exerted by firing pin holder.

① (Continued)—Continuous-pull type (firing lock M-13).



② Percussion-hammer type.

FIGURE 10 (continued).—Firing mechanisms.

the lanyard is released, or it may be directly actuated by the pull of the lanyard. Guns firing separate-loading ammunition are equipped with a firing-block assembly which carries the firing pin and which is removed from the breech in order to insert a primer.

b. With the type of device illustrated, a spring holds the firing pin in its rearward position. A strong pull on the lanyard

forces the hammer sharply against the firing pin. Upon release of the lanyard the hammer falls back to its original position. It should be noted that by moving the housing to the rear with respect to the pivot of the hammer contact between the hammer and the firing pin can be prevented.

c. The greatest advantages of this type of mechanism are simplicity and ruggedness.

d. Examples of the percussion-hammer type of firing mechanism will be found on the 75-mm. gun, M1897 (French), the 155-mm. howitzer, M1918A1, the 155-mm. gun, M1918 (GPF), and the 240-mm. howitzer, M1918.

22. **Operating mechanism.**—The operating mechanism consists of a handle and other parts necessary in opening and closing the breechblock. The simplest type of mechanism consists of a handle and a latch for the securing of the breech in a closed position, such as is found with the eccentric-screw type of breechblock. The sliding-block type of breechblock requires, in addition, parts necessary to cam the block from one position to the other. With the interrupted-screw type, there is required a mechanism for rotating the block, and a block carrier, which is hinged to the side of the breech for swinging the block clear of the breech recess for loading. A spring counterbalance is also necessary on the 155-mm. gun (GPF).

23. **Safety devices.**—There are various forms of safety devices intended to prevent accidents, including:

a. Those to prevent operation of the firing mechanism unless the breechblock is fully closed.

b. Those to prevent firing when the gun is not in battery.

c. Those to prevent firing when the gun is disconnected from the recoil system.

CARRIAGES

24. **General.**—A gun carriage is an assembly which furnishes a support for the gun in firing and, in addition, on mobile carriages, enables the gun to be moved readily from one position to another. The early types of mobile carriages consisted chiefly

of two wheels, an axle, and a trail. However, with increased performance of the gun, carriages had to be altered so as to reap the full benefits of changes in gun construction. Means for controlling recoil, for elevating, and for traversing are of the utmost importance. Modern carriages are a compromise between the various ideal characteristics. Usually, the ideal can be attained in any one characteristic, only with a corresponding decrease in some other characteristic. The carriage often determines the success or failure of any particular type of materiel in battle. As a result, primarily, of the great improvement in welding technique, and with improved testing of welds by means of X-ray photography, weights of gun carriages of a required strength have been considerably reduced. Nearly all carriages of the latest types use a minimum of castings and forgings and a maximum of built-up, welded, nickle-steel construction. Also, as a result of the great advances in motor transportation, carriages have had to be adapted for high-speed travel. These differences are the outstanding changes in construction since the World War. The essential characteristics as proposed for the ideal by the "Caliber Board" have in many cases been exceeded, largely as a result of the above mentioned improvements in methods of construction and of the forced requirements of new methods of tactics to meet a differently organized foe than that of the World War period. The cry for longer ranges has forced a great increase in elevation, this in most cases requiring the use of split trails and variations in elevating mechanisms. The probable necessity of firing on rapidly moving targets calls for increased flexibility in traversing and elevating mechanisms. These characteristics are generally obtained only at the expense of others; such as fire power, time of emplacement, ruggedness, and simplicity. By improved methods of manufacture we have gained greater range, mobility, and flexibility of traverse and elevation, but with the loss of simplicity, weight, and, to some extent, time required for emplacement. Depending upon the essential characteristics desired for the weapon, modern carriages may consist of some of or all the following components or assemblies: *Recoil system, equilibrator, sleigh, cradle, top carriage, bottom carriage, elevating mechanism, traversing mechanism, axle, equalizer, firing jack, trail, wheels, brakes,* and *shield.*

RECOIL SYSTEM

25. General.

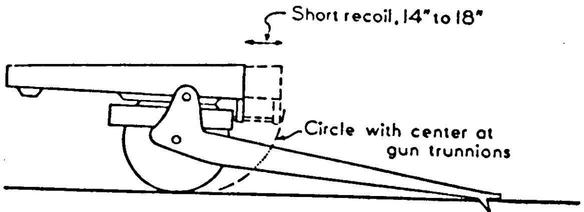
a. In early types of mobile cannon, each round fired rolled the carriage back several feet (recoil). The cannoneers then pushed the carriage up into the firing position again (counterrecoil). Modern guns employ a built-in recoil system which controls the forces incident to firing, so that the carriage remains in place. In such a system, a series of mechanisms controls the rearward movement and limits its length, returns the gun to the firing position and holds it there, and diminishes the shock as the gun returns to its firing position. The recoil system may be housed in either the cradle or the sleigh. The use of recoil systems directly results in increased stability, rate of fire, and flexibility, and indirectly contributes to greater ranges and accuracy.

b. A recoil system consists of three distinct elements; namely, a *recoil brake*, a *counterrecoil mechanism*, and a *counterrecoil buffer*. According to the length of recoil at varying elevations, recoil brakes are termed as *constant recoil* or *variable recoil.*

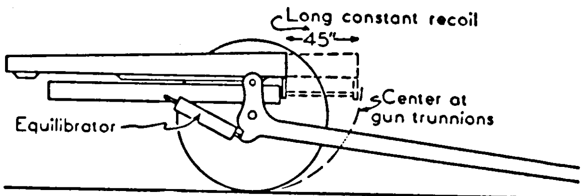
26. Long, short, and variable recoil.

a. Short recoil (Fig. 11 ①).—A short-recoil weapon is one which has a constant, relatively short length of recoil at all elevations. This system can be simple, sturdy, and comparatively light, but has the great disadvantages of poor stability and increased stresses in the carriage.

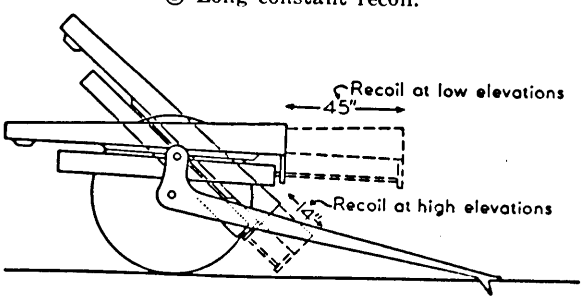
b. Long recoil (Fig. 11 ②).—A long-recoil weapon is one which has a constant, relatively great length of recoil at all elevations. This is desirable in a gun carriage, since the resistance of the recoil brake can be comparatively small and the stresses in the carriage correspondingly light. This system can be simple and rugged, but, if the breech in recoil at extreme elevations is to clear the ground, has the disadvantage of requiring either high trunnions or *rear trunnions*. Rear trunnions necessitate the use of equilibrators. The balancing of the gun on central trunnions requires increased height and results in a loss of stability in firing and traveling. If the cradle trunnions be placed well to the rear, instead of at the center of gravity of the tipping parts, the breech is not lowered materially in elevating the piece.



① Short constant recoil.



② Long constant recoil.



③ Variable recoil.

FIGURE 11.—Classification of recoil systems as to length of recoil.

This permits the use of constant recoil at all elevations, without the breech striking the ground. Since the tipping parts are not balanced about the trunnions, it is necessary to introduce *equilibrators* to equalize the forces required to elevate and to depress the piece. The use of equilibrators adds weight and complication to a carriage, but the present tendency favors their use instead of the use of variable recoil.

c. Variable recoil (Fig. 11 ③).—Variable recoil, a combination of long and short recoil, is obtained by devices which automatically increase the resistance in the recoil brake as the piece is elevated. Thus, there is the minimum resistance at low elevations, where it is most difficult to secure stability, and the maximum resistance at high elevations, where the recoil must be

short in order to avoid striking the ground. The mechanism, somewhat complicated, requires a reduction in the area of the throttling orifice as the piece is elevated. A variable recoil has the advantage of permitting the use of balanced weight at the trunnions without the necessity of digging recoil pits for higher elevations.

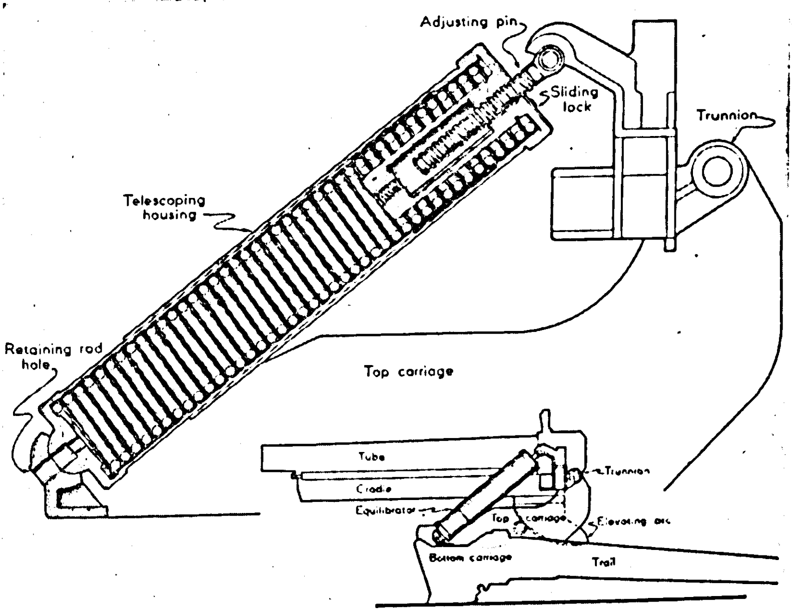


FIGURE 12.—Spring equilibrator.

27. **Equilibrators (Fig 12).**—An equilibrator is a device which overcomes the unbalanced weight of a gun by exerting a pressure against the muzzle preponderance. This muzzle preponderance can be overcome by the use of counterweights on the breech end (as on the 155-mm. howitzer, M1918) to equalize the weight and to bring the center of mass near the axis of rotation. An crease in total weight is naturally objectionable. The equilibrator makes the use of counterweights unnecessary and assists in elevating the gun. It may bear upward or pull downward between the cradle and some lower part of the carriage. In general,

an equilibrator consists of an arm rigidly attached to the cradle trunnion, which carries at its outer end a telescopic cylinder containing a piston and piston rod which bears against a lug on the carriage. The cylinder contains either compressed air or a helical spring expanding against the piston. The piston rod thus exerts a varying pressure against the lug and tends to elevate the piece. Pneumatic equilibrators have been used on some carriages, but the present trend, especially on light artillery, appears to be toward the use of spring equilibrators. Spring equilibrators are often additionally classified as *bent-pin type* or *straight-pin type*. This refers to the connection at the arm of the trunnion, the straight pin having a straight shank and the bent pin having a shank bent near the top of the equilibrator cylinder.

28. Recoil brakes.

a. General.—A recoil brake is a mechanism which cushions the shock of discharge of a gun by allowing, controlling, and checking its rearward movement with respect to the carriage. Although friction or pneumatic types have been used, all modern recoil brakes are hydraulic. Each consists essentially of a piston moving in a cylinder filled wtih liquid. Either the cylinder or the piston is attached to the gun near the breech and recoils with it. The other part is fixed to the cradle. In either case, when the gun is fired, relative motion is given to the cylinder and to the piston head, and provision is made for the passage of liquid from one side of the piston head to the other by an aperture cut in the piston or in the walls of the cylinder. Assume that in Figure 13 the piston head is held stationary and the cylinder is moving in the direction indicated by the arrow. The liquid to the left of the piston is under pressure, and its only escape is through the orifice (portion of the aperture open to the flow of the liquid) in the piston head into the portion of the cylinder to the right of the piston. It is evident that, first, the liquid displaced by the piston head in a given time must pass through the orifice in the same time; secondly, the velocity of the liquid through the orifice is greater than the velocity of the piston; and thirdly, the work done by the liquid in bringing the piston to rest at the end of recoil must equal the energy of the moving parts. If, as in the figure, the area of the aperture is constant,

it follows that the resistance to flow varies as the velocity of recoil. The power of the brake lies in the pressure produced in the cylinder by the resistance to flow of the liquid through the orifice. Under the above conditions, the maximum resistance to the movement of the gun occurs immediately upon discharge and enormous strains are placed on the recoil mechanism. If, however, the aperture is so constructed that the area of the orifice decreases as the velocity of the piston decreases, the variation in the size of orifice may be so regulated that the pressure in the cylinder

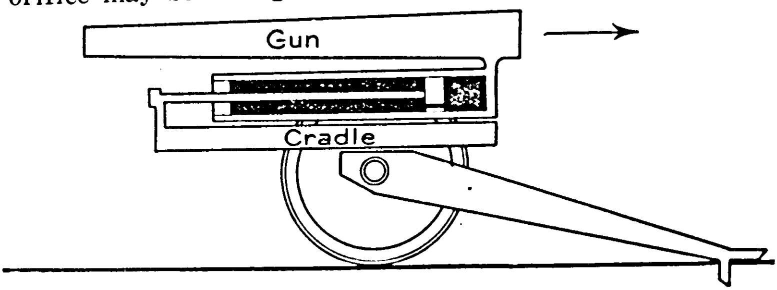


FIGURE 13.—Hydraulic recoil brake.

will be constant throughout recoil, or will vary as desired. Since it is necessary to distribute the resistance more or less uniformly throughout recoil, it is necessary that the opening be relatively large at the beginning of recoil and decrease as the recoil progresses. The variation of the orifice is determined with great care so as to secure maximum stability of the carriage during recoil. Several mechanical devices may be used in order to obtain this variable area of the throttling orifice. The principles of all systems are similar.

b. Throttling grooves (Fig. 14).—Throttling grooves are tapered slots or grooves cut into the cylinder walls. These grooves are cut in such a manner as to have the greatest depth, and thus the greatest area of aperture, at the beginning of recoil and the least depth at the end of recoil, the area of orifice through which the liquid can flow being determined by the position of the piston head. As the velocity of recoil decreases, a smaller orifice thus is presented, until, at the position of extreme recoil, the piston head completely fills the cylinder, no more liquid can pass, and the gun is brought to rest. A variation of this method

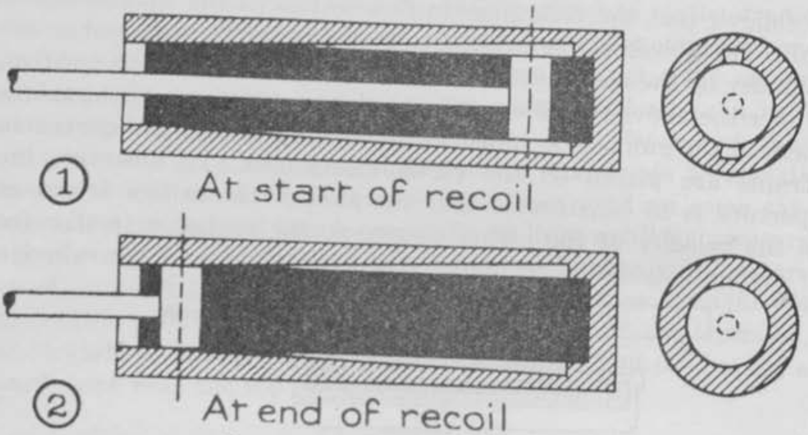


FIGURE 14.—Throttling grooves.

is the use of *throttling bars,* the piston being cut out to clear tapered bars secured to the side walls of the piston. The principle is identical.

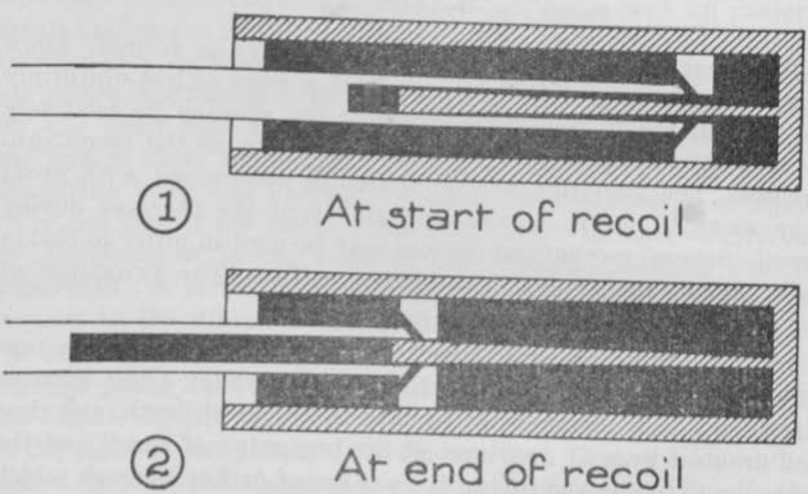


FIGURE 15.—Central throttling rod.

c. Throttling rods (Fig. 15).—A central throttling rod obtains a variable area of orifice by means of a tapered rod through a throttling ring. In the firing position the smallest section of the tapered rod is resting in the throttling ring, providing the maxi-

mum throttling orifice when the gun is fired. As the gun recoils the cylinder and the tapered rod move to the rear, the hollow piston rod being held stationary. Liquid to the left of the piston is forced into the central portion of the hollow piston rod and then through the throttling orifice to the right side of the piston. The tapered rod, being drawn through the throttling ring, gradually diminishes the size of the orifice until, in the position of extreme recoil, the rod completely fills the throttling ring, no more liquid can pass, and the gun is brought to rest.

d. A variation of the central throttling rod is used in many recoil brakes of field artillery weapons, including the 75-mm. gun, M1897, and the majority of 75-mm. and 105-mm. carriages designed since the World War. In this variation two cylinders (Fig. 16) are connected by a communicating channel, one cylinder

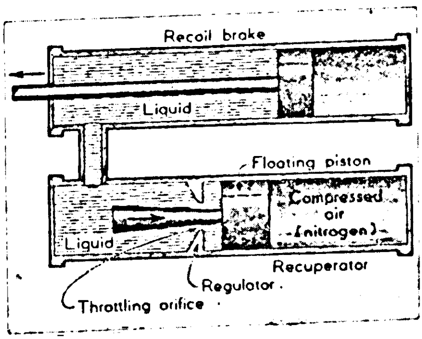


FIGURE 16.—Recoil brake with floating piston.

carrying a piston which is connected to either the tube or the carriage, and the other cylinder carrying a *regulator* and *floating piston*. On recoil the oil from the cylinder containing the fixed piston is forced into the connecting cylinder, through one-way valves in the regulator, and between the regulator and a central throttling rod which moves with the floating piston.

e. Variable recoil.—A variable recoil mechanism reduces the length of recoil as the elevation of the gun increases.

29. Counterrecoil mechanisms.

a. General.—A recuperator, or counterrecoil mechanism, is a device which forces the gun back to its firing position from its position in recoil and holds the gun in its firing position during

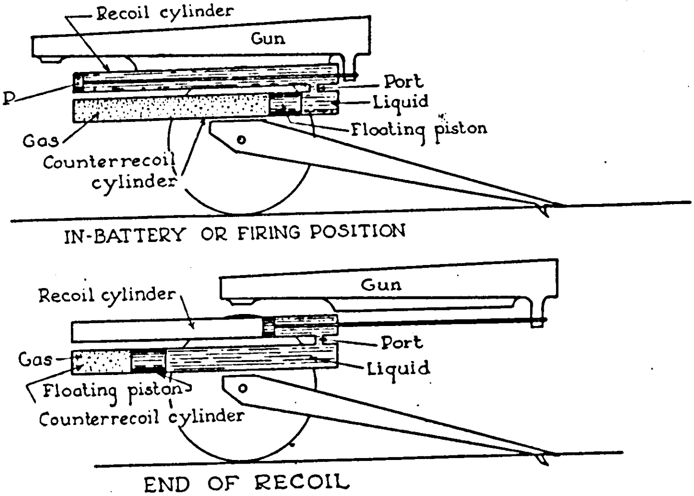
travel and prior to firing. There are two types of counterrecoil mechanisms, *pneumatic* (compressed gas) or *spring*, depending upon the means used to store up the energy necessary to secure functioning.

b. Pneumatic counterrecoil mechanisms (Fig. 17).

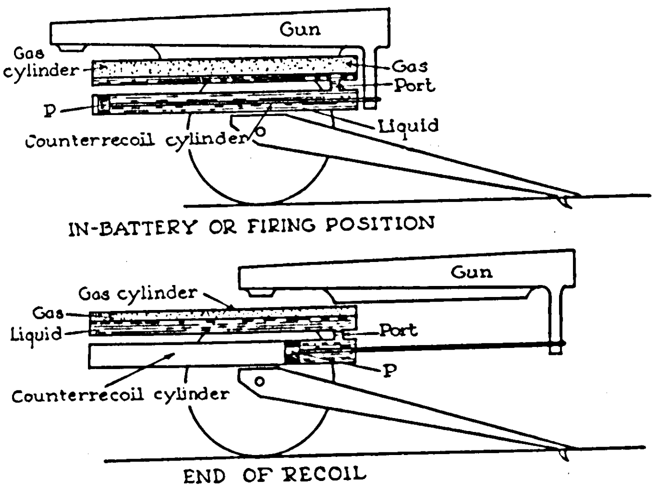
(1) There are two designs in general use in our artillery. In one the gas is separated from the liquid by a *floating piston*, and in the other the gas is in *direct contact* with the liquid.

(2) In the *floating piston type* (Fig. 17 ①) the recoil-brake cylinder is connected to the counterrecoil cylinder by an open port. Moving freely in the counterrecoil cylinder is the floating piston, which is designed and fitted so as to form a movable, gastight, and liquidtight seal between the gas at one end of the cylinder and the liquid at the other. As the gun recoils, carrying with it the recoil-brake piston, the liquid is forced by the piston through the port into the rear of the counterrecoil cylinder, thus forcing the floating piston forward against the compression of the gas. (Either the recoil-brake cylinder or the recoil-brake piston may be attached to the gun and the same relative motion will result). The gas pressure assists in checking the recoil, and, at the completion of recoil, forces the floating piston to the rear, driving the liquid back through the port and against the recoil-brake piston, forcing it forward and drawing the gun back into battery. The initital gas pressure is made sufficiently great to hold the gun in battery at any elevation. The principle of this type of construction is extremely simple. However, in actual construction it is difficult, under the high pressures encountered, to obtain and maintain an absolutely gastight and liquidtight seal between the floating piston and the walls of the counterrecoil cylinder. The walls of the cylinders are lapped to a very small tolerance, and only chemically nonactive ingredients are used. In practice, a breaking down of the seal between the floating piston and the highly polished wall of the cylinder may be detected by an emulsification of the oil.

(3) In the *direct-contact type* (Fig. 17 ②) the recoil-brake cylinder and the counterrecoil cylinder are not connected, but function separately and independently. In the counterrecoil mechanism a counterrecoil cylinder provided with a liquidtight piston is connected by ports to one or more cylinders placed above it



HYDROPNEUMATIC RECOIL & COUNTERRECOIL SYSTEM
With floating piston
①



HYDROPNEUMATIC COUNTERRECOIL SYSTEM WITH
LIQUID IN DIRECT CONTACT WITH GAS
(Recoil system not shown)
②

FIGURE 17.—Pneumatic counterrecoil mechanisms.

serving as reservoirs for liquid and gas. In general, the system is supplied with liquid sufficient to fill the counterrecoil cylinder completely and the reservoir cylinders about one half. The remaining space in the reservoirs is filled with gas under a pressure sufficient to hold the gun in battery. The counterrecoil cylinder is connected to and recoils with the gun. When the piece is fired, liquid is forced by the piston through the ports into the reservoir cylinders, further compressing the gas therein, and assisting the recoil brake in checking the recoil. Upon completion of recoil, the gas pressure, acting in the opposite direction, returns the gun into battery. In the construction of this type of mechanism, the various cylinders are usually bored directly into a member of the carriage called the sleigh. As there is no floating piston, the finish of the surfaces and the selection of metals for components are not of so much importance.

(4) The advantage of the floating-piston type over the direct-contact type is its light weight, a feature especially desirable in a light field artillery piece. The advantages of the direct-contact type are ease of manufacture, better functioning under the greater stresses of the heavier pieces, and independence of the recoil brake and the counterrecoil mechanism.

(5) Reliability of performance, great durability (20,000 to 40,000 rounds), smooth action, compactness, and adjustability to slight variations of temperature and pressure are advantages of a pneumatic counterrecoil mechanism. Great initial cost, necessity for specialized manufacture and maintenance, and difficulty of maintaining in storage are disadvantages.

(6) Examples of the floating-piston type are found on the 75-mm. gun, M1897, 75-mm. howitzers, M1, M3, and M3A1, 105-mm. howitzer, M1, and 155-mm. gun, M1918A1 (GPF). Examples of the direct-contact type are found on the 155-mm. howitzer, M1918A1, and the 240-mm. howitzer, M1918.

c. *Spring counterrecoil mechanism* (Fig. 18).

(1) In this type of mechanism the gun is retained in battery or returned to battery from its recoiled position by the action of springs which are assembled under an initial compression. The springs may be arranged in many ways; such as, a single spring column composed of two or more short sections separated by spacers, two or more concentric columns (Fig. 18 ①),

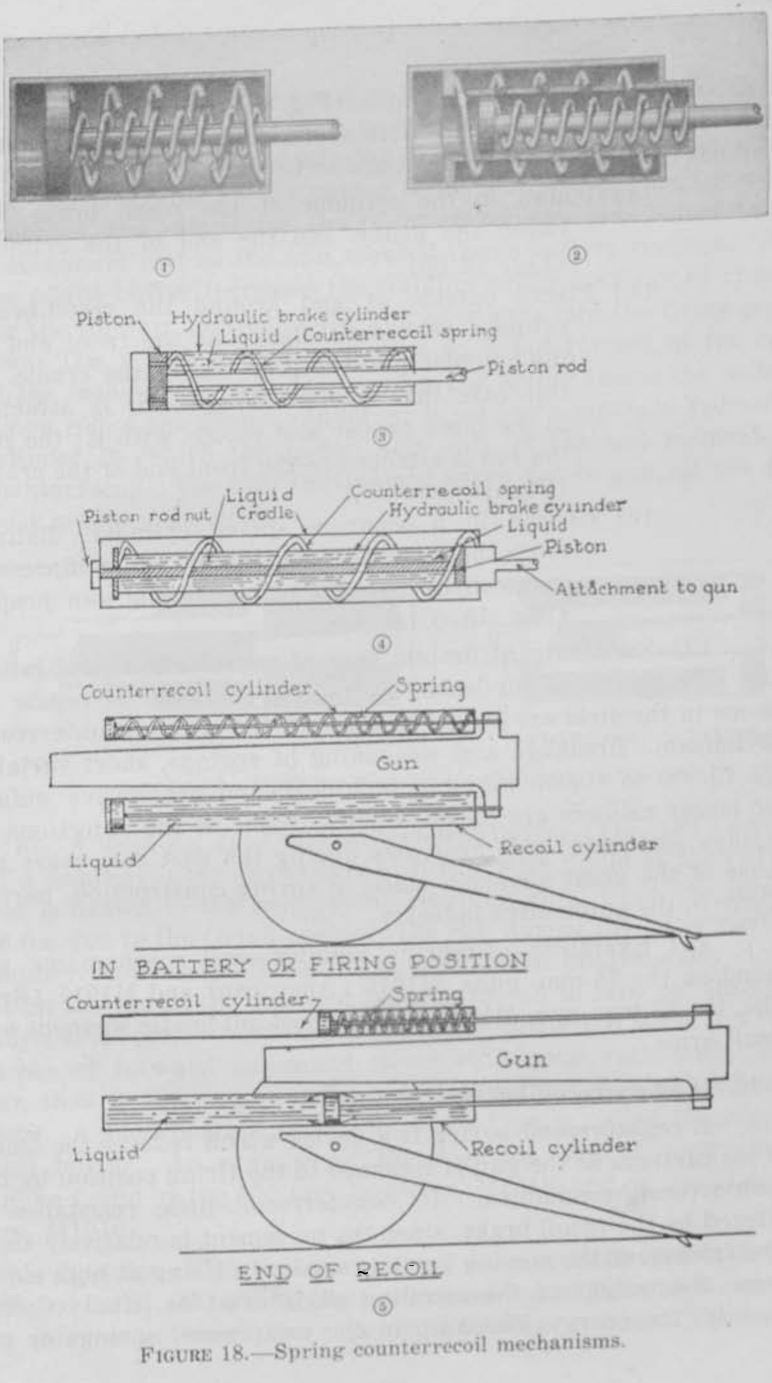


FIGURE 18.—Spring counterrecoil mechanisms.

or telescoping concentric columns (Fig. 18 ②). The two latter methods permit longer recoil with shorter spring columns. Three methods of spring arrangement are as follows:

(a) Placed in the cylinder of the recoil brake, between the piston and the end of the cylinder (Fig. 18 ③).

(b) Placed outside of and around the recoil-brake cylinder between a flange at the front end of the cylinder and the rear end of the cradle. In this case the recoil-brake cylinder is attached to the piece proper and recoils with it; the piston rod is attached to the front end of the cradle (Fig. 18 ④).

(c) Housed in a separate spring cylinder, distinct from the recoil brake cylinder, and compressed in recoil by a rod attached to the gun proper (Fig. 18 ⑤).

(2) Simplicity of design, ease of manufacture, low initial cost, elimination of air-leakage problem, and ease of repair by troops in the field are the advantages of the spring counterrecoil mechanism. Breakage and weakening of springs, short variable life (3,000 to 10,000 rounds), bulkiness, and prohibitive weight for larger calibers are disadvantages. Some of the objections to springs may have been overcome during the past few years because of the great advances made in spring construction, particularly in the automotive industry.

(3) Examples of spring counterrecoil mechanisms are found on the 75-mm. guns, M1916 (American) and M1917 (British), the 37-mm. gun, M1916, and on most automatic weapons and small arms.

30. Counterrecoil buffers.

a. A counterrecoil buffer is a device which reduces the shock to the carriage as the gun is returned to the firing position by the counterrecoil mechanism. In counterrecoil little resistance is offered by the recoil brake, since the movement is relatively slow. The friction of the moving parts is small. In firing at high elevations, the weight of the recoiling parts must be lifted. Consequently, the energy stored up in the compressed springs or gas

is sufficient to return the gun to battery with considerable speed, particularly at low elevations, and, unless cushioned in some way, excessive shock occurs, rendering the carriage unstable and bringing undue strains on the parts. If no counterrecoil buffer were provided, the velocity of the counterrecoiling mass would be at a maximum just as the gun reached the in-battery position. The use of the buffer increases the stability of the carriage by checking the forward motion of the gun as it runs into the firing position. The buffer may consist of a dash pot formed at the end of the recoil-brake cylinder, or of a rod acting inside the hollow piston rod of the recoil cylinder, or it may be a separate hydraulic cylinder in which the piston acts only at the last moment of counterrecoil. The two first-named types are in general use for field artillery materiel.

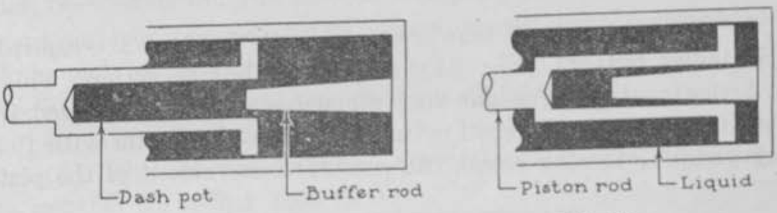


FIGURE 19.—Dash-pot type of counterrecoil buffer.

b. A *dash-pot type* of counterrecoil buffer (Fig. 19) consists of a small cylinder or cavity which fills with liquid as the buffer rod is drawn to the rear by the recoiling gun. Upon the return of the gun to the firing position, the rod, during the latter part of counterrecoil, enters the oil-filled cavity. The progressively closer fit on the rod in the dash-pot permits the oil to flow out through only a small orifice, and the motion of the buffer rod in the last few inches of forward movement meets with great resistance. The gun thus is eased into firing position without jarring the carriage. A modification of the dash-pot type is called the spear-head buffer. An example of the dash-pot type of mechanism will be found on the 155-mm. howitzer, M1918, and on the 37-mm. gun, M1916.

c. One design of the *internal-rod type* of buffer consists of a tapered rod (throttling bar) which moves relative to a sleeve, the interior of which has tapered throttling grooves. The area

of the throttling grooves is gradually diminished as the head on the end of the throttling bar approaches its in-battery position. This condition causes the gun to come to rest slowly in its counter-recoil movement. A modification of this type of mechanism as found on the 75-mm. gun, M1897 (French), is shown in Figure 20.

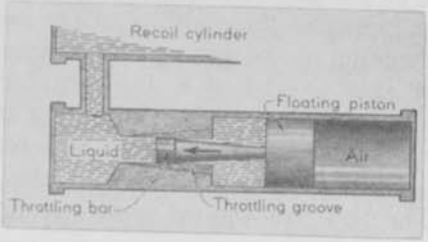


FIGURE 20.—Internal-rod type of counterrecoil buffer.

d. Though not a true counterrecoil buffer, a *respirator* (Schindler buffer) (Fig. 21), may assist buffer action. This is a device containing a one-way air valve which is screwed into the front end of the recoil cylinder (hydro-pneumatic with floating piston). During recoil, the rearward movement of the piston

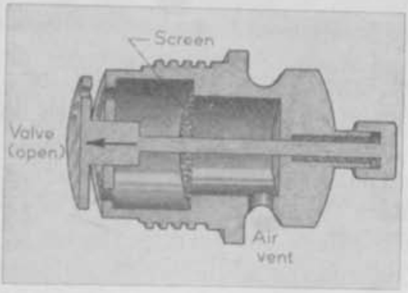


FIGURE 21.—Respirator (Schindler buffer).

causes air to be drawn in from the outside, the buffer valve opening to pressure from that side only. During counterrecoil the valve is closed. The air, now compressed by the returning piston, is permitted to escape through a hole of a selected size, thereby acting as a buffer near the end of counterrecoil. An example of this mechanism will be found on the 75-mm. gun, M1897 (French).

31. Summary.

a. The total resistance to recoil offered by a recoil system is made up of three principal components:

(1) That of the recoil brake.

(2) That due to friction of the moving parts.

(3) That of the counterrecoil mechanism in compressing the springs or gas.

b. When the total resistance to recoil is equal to the energy of recoil, the piece will be momentarily at rest. The stored up energy in the counterrecoil mechanism then acts in the opposite direction, at first slowly, but with a rapidly increasing velocity. Toward the end of the counterrecoil phase it is necessary to decrease the velocity, and this is done by means of the buffer which then eases the gun into its firing position.

c. Complete characteristics for a recoil mechanism should include each of the following:

(1) Type of recoil (constant or variable).

(2) Length of recoil.

(3) Type of recoil brake (throttling grooves, throttling bars, central throttling rod, etc.).

(4) Type of counterrecoil mechanism:

(a) Pneumatic (direct contact or floating piston).

(b) Spring (placing of springs and cylinders).

(5) Type of buffer (dash pot, spearhead, central throttling rod, etc.).

(6) Capacity of cylinders (oil).

(7) Air pressure (if any).

SLEIGH, CRADLE, TOP CARRIAGE, AND BOTTOM CARRIAGE

32. Sleigh (Fig. 22).—The *sleigh* is a part of the carriage, which, when present, houses the recoil mechanism and recoils with the barrel on the cradle. A sleigh is used only when the recoil system is so designed that the cylinders move in recoil and the piston and rod remains in place. In some cases the recoil cylinders may be bored directly into the sleigh; in others the cylinders are separate tubes assembled and then rigidly attached. Means must be provided to secure the gun rigidly to the sleigh and to form a finished surface of contact between the sleigh and

the cradle during recoil. In most cases, the barrel is attached to the upper surface of the sleigh, and the cradle encloses a sufficient portion of the sides of the sleigh to prevent upward or lateral movement. In a few cases, such as the 75-mm. howitzer,

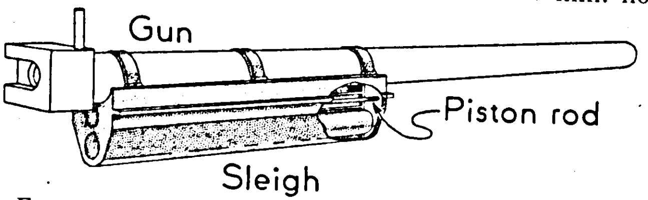


FIGURE 22.—Sleigh, carrying gun and recoil mechanism.

M1, the sleigh encircles the barrel and is divided into a top and a bottom sleigh. The chief advantages of a sleigh are an increase in the weight of recoiling parts, thus giving better stability with a lighter carriage, and the simplified requirements of mounting the gun and recoil system on the sleigh and the sleigh on the cradle. Examples are found on the 75-mm. howitzers, M1, M3, and M3A1, the 155-mm. howitzer, M1918A1, and the 240-mm. howitzer, M1918.

33. **Cradle (Fig. 23).**—The *cradle* is the part of the carriage which supports the gun and sleigh. Where no sleigh is used the cradle houses the recoil mechanism. In general, the cradle is a U-shaped trough which has slides or roller paths along which the

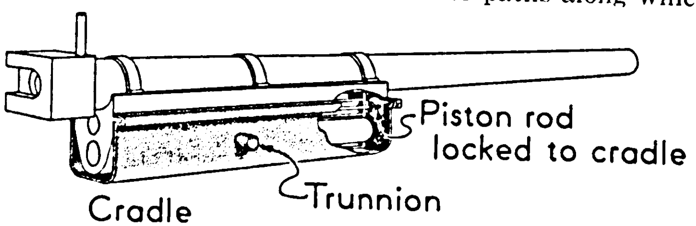


FIGURE 23.—Cradle.

gun recoils in firing. It provides means of securing the piston rod or rods, where a sleigh is used and provides mountings for the cylinders if no sleigh is used. It has trunnion bearings which furnish an axis about which the cradle, and hence gun, rotates in elevation. Runways on the cradle form surfaces upon which the gun or sleigh recoils directly to the rear. Manufacturing tolerances

permit a slight lateral play. If the motion of the tube assembly during recoil is in a plane parallel to the cradle, the connection between the piston rod and cradle (with sleigh, otherwise between piston rod and tube assembly) may be rigid. However, if this motion is through a slight angle with respect to the cradle, such as occurs in weapons with inclined planes, a flexible connection is necessary. The trunnions rest in trunnion bearings on the lower part of the carriage. The cradle may be constructed from a forging or by built-up welded construction. The latter type offers equal strength with less weight. A cradle is a necessary assembly in all modern field artillery weapons.

34. **Top carriage (Fig. 24).**—The *top carriage,* when present, supports the cradle in its trunnion bearings and carries most of the elevating mechanism. It moves with the cradle in traversing but not in changes of elevation. In traversing it pivots on the axle or (lower) carriage. In cases where a top carriage is not used, its function is performed by the upper front part of the trail. In general, a top carriage is required when split trails

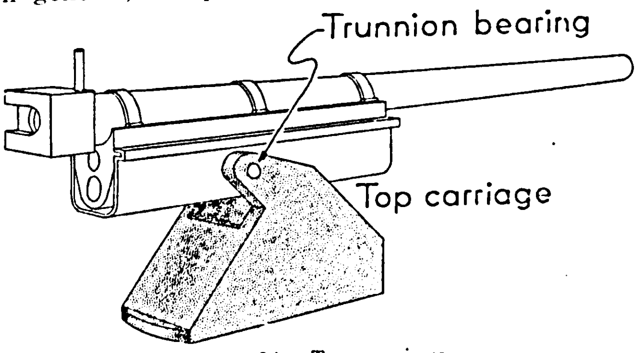


FIGURE 24.—Top carriage.

are used. Thus, it has the advantage of giving increased flexibility to the piece, usually at the disadvantage of increased weight. Examples of top carriages are found on the later-model weapons such as the 75-mm. howitzers, M1, M3, and M3A1, and the 75-mm. gun, M2, and on heavier carriages such as the 155-mm. gun, M1918A1 (GPF), and the 240-mm. howitzer, M1918.

35. **Bottom carriage (Fig. 25).**—The *bottom carriage* is that part of the carriage assembly which, when present, supports the

top carriage and has attached to it portions of the mechanism for rotating the top carriage with respect to the bottom carriage. It may have the trail end (or ends) attached, and one end of the firing jack will, if present, be attached to the bottom carriage. The bottom carriage may be fixed to the axle, or it may replace the axle, acting as a bogie. Where there is no axle or trail, a type of bottom carriage known as a *platform* may be used. Normally, the bottom carriage contains a portion of the

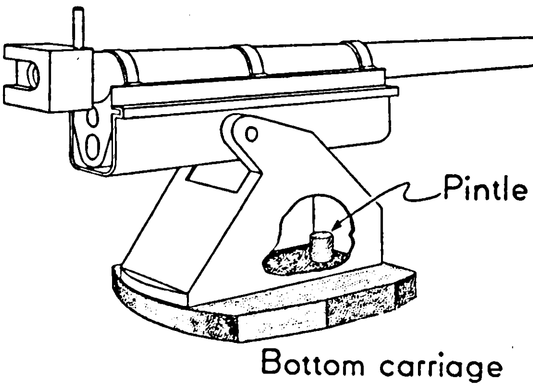


FIGURE 25.—Bottom carriage.

traversing mechanism, and it carries the *pintle* on which the top carriage swings in traverse. The pintle may consist of a vertical pin or bolt. Modern bottom carriages are usually constructed by means of built-up welded nickel steel. This offers many advantages over large cumbersome castings, particularly, simplicity and flexibility of manufacture, light weight, and uniform strength. It also assists in obtaining large traverse. The majority of the newer mobile carriages both in this country and abroad are equipped with a bottom carriage. Examples of bottom carriages may be found on the 75-mm. howitzers, M3 and M3A1, the 75-mm. gun, M2, and the 155-mm. gun, M1918A1 (GPF). The platform type is found on the 240-mm. howitzer, M1918. The apparent trend in construction is to use the bottom carriage to support the top carriage and cradle, to carry the traversing mechanism, to furnish a means of attachment to the trails, and, in addition, to act as a bogie to replace the axle and to carry the wheels.

ELEVATING MECHANISM

36. General.

a. An elevating mechanism (Fig. 26) consists of devices for placing and holding the axis of the bore at a desired inclination with a horizontal plane. All modern carriages are equipped with an elevating mechanism which gives the necessary flexibility of elevation. Weapons which are designed to fire at low elevations require the minimum amount of mechanism, while those designed to fire at high elevations require more complicated and heavier mechanisms.

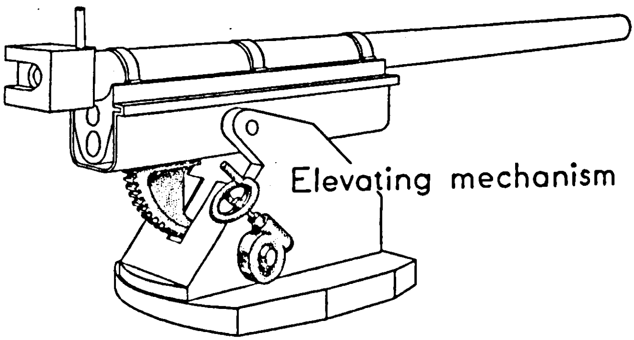


FIGURE 26.—Elevating mechanism.

b. In order that a projectile fired from a gun may reach a given target, the gun must be laid with a predetermined quad-

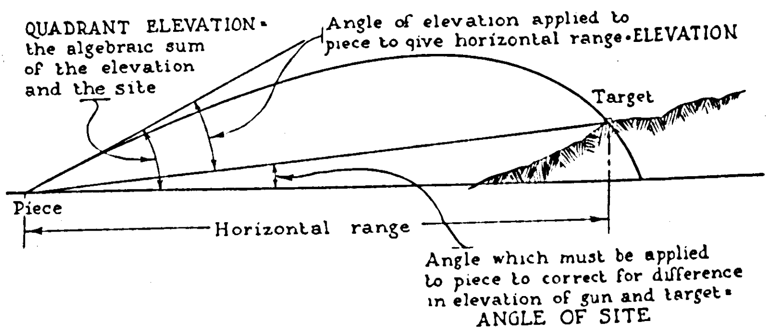


FIGURE 27.—Elements of quadrant elevation.

rant elevation (Fig. 27). This angle is composed of two elements: First, the elevation required to fire at the horizontal range to the target; and second, the elevation correction to take

care of the difference in altitude between the piece and the target.

37. Types of elevation-laying devices.

a. General.—Elevation-laying devices are divided into three general types or systems according to the relation between the angle-of-site and the range-elevation mechanisms; namely, *dependent, independent,* and *semi-independent* systems. All types are represented on carriages now in our service, so a complete understanding of the differences is important to the field artillery officer.

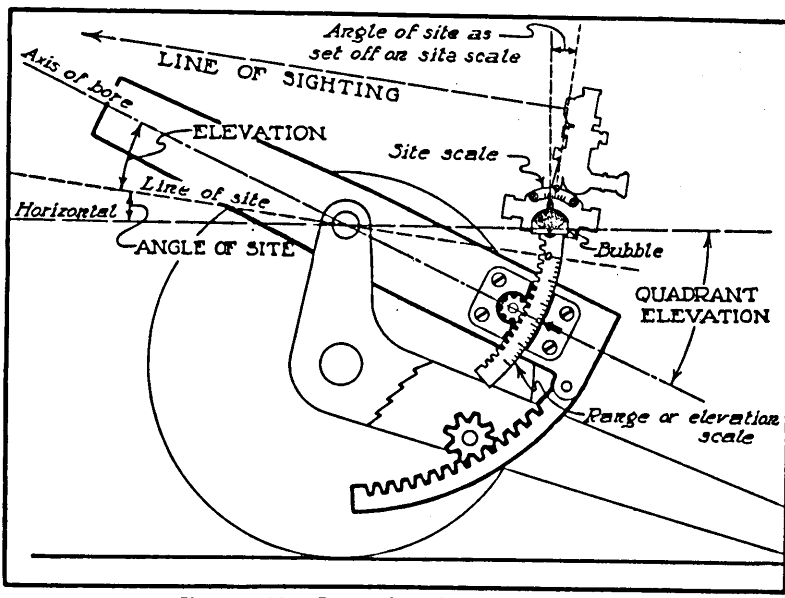
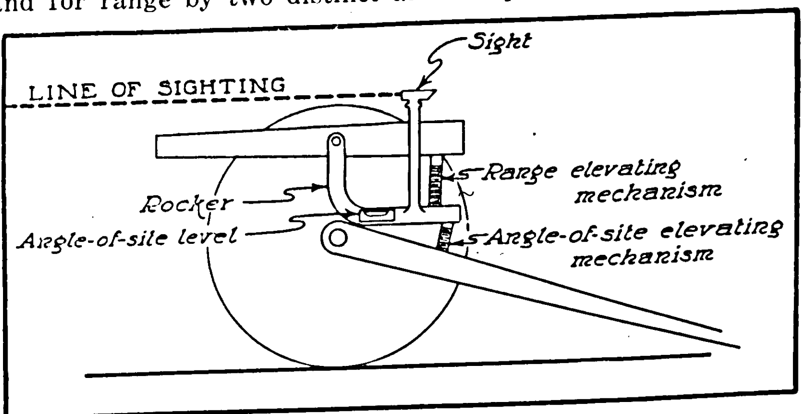


FIGURE 28.—Dependent line of sighting.

b. Dependent line of sighting (Fig. 28).—A dependent line of sighting is one in which any movement of the elevation mechanism moves the tube and the line of sighting simultaneously. On the particular design illustrated the angle-of-site level is attached to the movable part of the range or elevation scale. Thus the level will move through a vertical arc as the elevation setting for range is changed. The angle-of-site level is provided with an operating device by means of which the appropriate angle of site can be set. A movement of this operating de-

vice moves the axis of the level with relation to the line of sighting through the telescope which is secured to the range or elevation scale. A movement of the elevation scale, in changing the setting for range, moves simultaneously both the line of sighting and the axis of the angle-of-site level. Thus, the single handwheel which moves the elevating mechanism moves the following parts as a unit through a vertical arc: Gun tube, line of sighting, axis of the angle-of-site level, and the range or elevation scale. For indirect laying the gun is laid for elevation when the appropriate settings for range and angle of site are opposite their respective indexes and the angle-of-site level bubble is centered. Thus, a change in either angle-of-site or range setting will throw the level bubble off center, requiring the movement of the elevating mechanism to recenter the bubble.

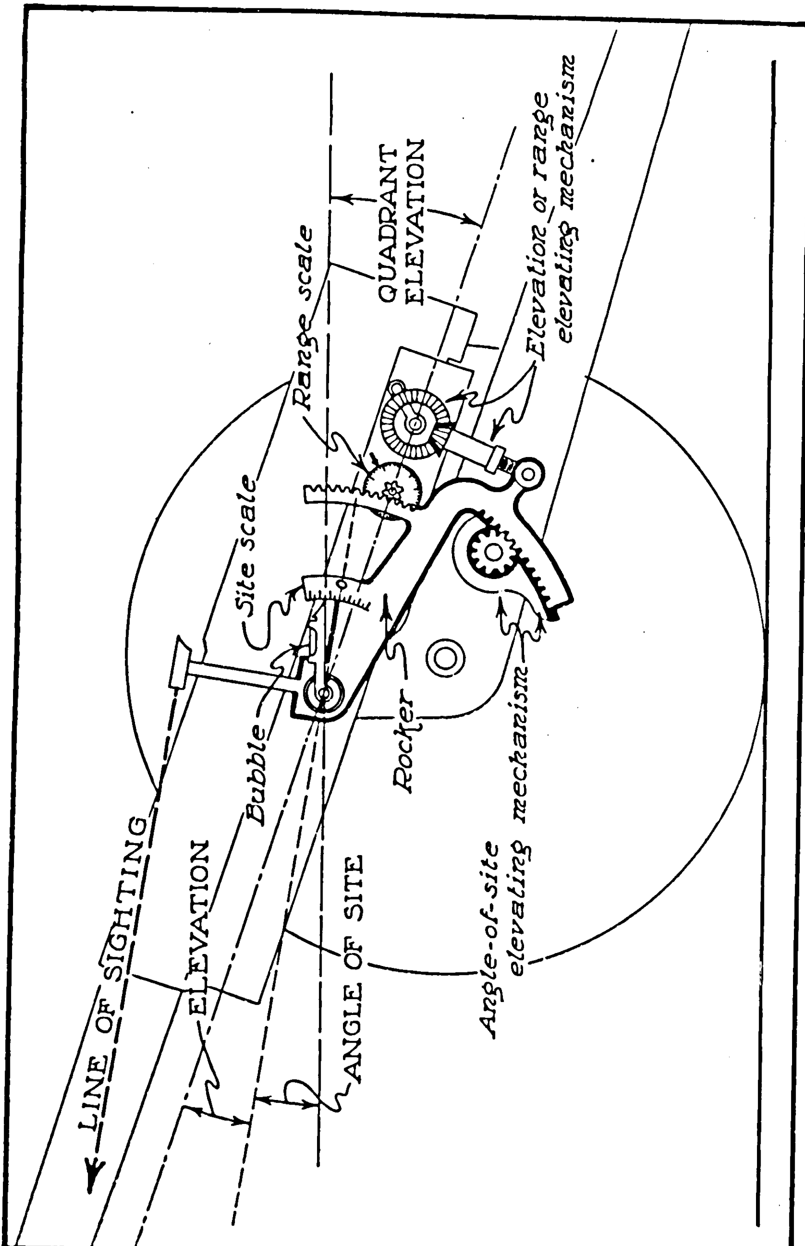
c. Independent line of sighting (Fig. 29).—An independent line of sighting is one in which the piece is laid for angle of site and for range by two distinct and independent elevating mechanisms.



① Schematic form.

FIGURE 29.—Independent line of sighting.

In this case a change in either element does not affect the laying for the other. Two separate and unconnected handwheels are used, one, the angle-of-site handwheel, moving the telescope, and the other, the range-elevating handwheel, moving without affecting the telescope. This type of elevation-laying device requires for the carriage an additional part known as a rocker, which is interposed between the cradle and the bottom



② 75-mm. gun, M1897 (French).

FIGURE 29 (continued).—Independent line of sighting.

carriage or trail. The telescope is attached to and moves with the rocker or a part serving in the same capacity. Movement of the angle-of-site handwheel thus moves the gun, rocker, and the telescope, while movement of the range-elevating mechanism moves the gun with respect to the rocker without moving the telescope. The angle of site is set on the proper scale and the bubble centered by the angle-of-site handwheel. The proper elevation is then (it may be done before or later) set off by means of the range-elevating handwheel, this handwheel moving the tube with respect to the rocker.

d. Semi-independent line of sighting.—A semi-independent line of sighting (Fig. 30) is one in which the piece is elevated for both site and range by a single mechanism, but the parts are so arranged that a change in one element will not affect the laying for the other. For all practical purposes it is an independent system except that it has a single handwheel which lays the piece for both site and range. Setting the angle of site on the scale moves the bubble out of level. The bubble is then leveled by means of the angle-of-site worm, which rotates the entire telescope and mount, thus moving the adjustable index away from the fixed index. However, if the angle-of-site and range-setting mechanism be removed to the right side of the piece, the telescope will not be affected except by a leveling of its longitudinal bubble which keeps the telescope in the vertical position. Setting the elevation by means of the elevating knob again moves the adjustable index with respect to the fixed index but does not affect the setting of the line of sighting, the angle of site, or the bubble. Next, the tube is moved by means of the elevating handwheel until the fixed index again corresponds to the adjustable index. This latter movement does not affect the setting of the telescope or mount in any respect, nor does the latter move when the piece is elevated or depressed. The fixed index is the only element of the sight and mount which moves with the cradle.

e. Advantages and disadvantages.

(1) *Dependent type.*

(a) *Advantages.*

1. Simplest to manufacture, to operate, and maintain.

2. Cheapest to manufacture.

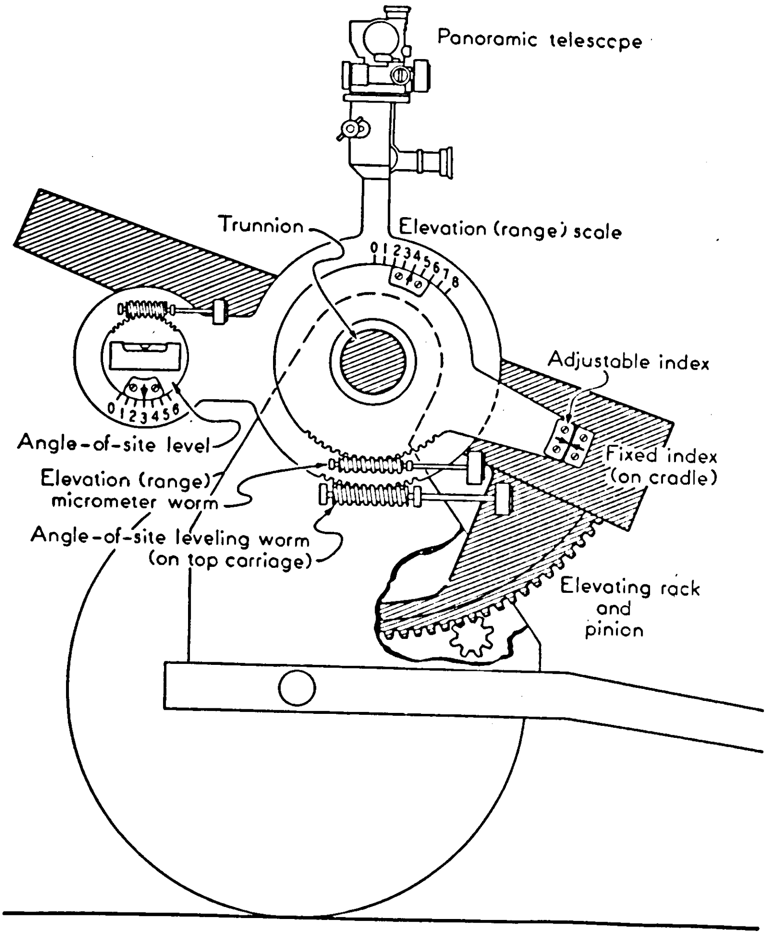


FIGURE 30.—Semi-independent line of sighting.

3. Easily adapted for direct laying.
4. Lightest in weight.

(b) *Disadvantages.*

1. Not readily adapted to higher rates of fire, owing to the unequal distribution of duties between the gunner and number one.
2. Change in either site or range affects the other.

(2) *Independent type.*

(a) *Advantages.*

1. Gives best distribution of duties between the gunner and number one, thus permitting a more rapid rate of fire.

2. A change in range does not affect site setting, and vice versa.

3. Better adapted to direct laying than semi-independent type.

(b) *Disadvantages.*

1. Complicated, particularly in design and manufacture.

2. Expensive.

3. Heaviest type.

(3) *Semi-independent type.*

(a) *Advantages.*

1. Secures most of advantages of the independent type without complications in carriage design and manufacture.

2. Lighter weight than independent type.

(b) *Disadvantages.*

1. Distribution of duties between gunner and number one are not as well balanced as in the independent system.

2. Not well adapted to direct laying.

3. Requires expensive and complicated telescope mount.

f. *Examples.*—Examples of the dependent system are found on the 75-mm. howitzers, M1, M3, and M3A1, the 155-mm. howitzer, M1918A1, the 155-mm. gun, M1918, and the 240-mm. howitzer, M1918. Examples of the independent system are found on the 75-mm. guns, M1897 (French), M1916 (American), and M1917 (British). Examples of the semi-independent system may be found on the 75-mm. gun, M2, and the 105-mm. howitzer, M1.

38. Construction (Fig. 31).

a. Regardless of the type of line of sighting, the mechanical means of elevating the piece are of two kinds, *rack and pinion* or *screw*. Generally, for the independent line of sighting, a

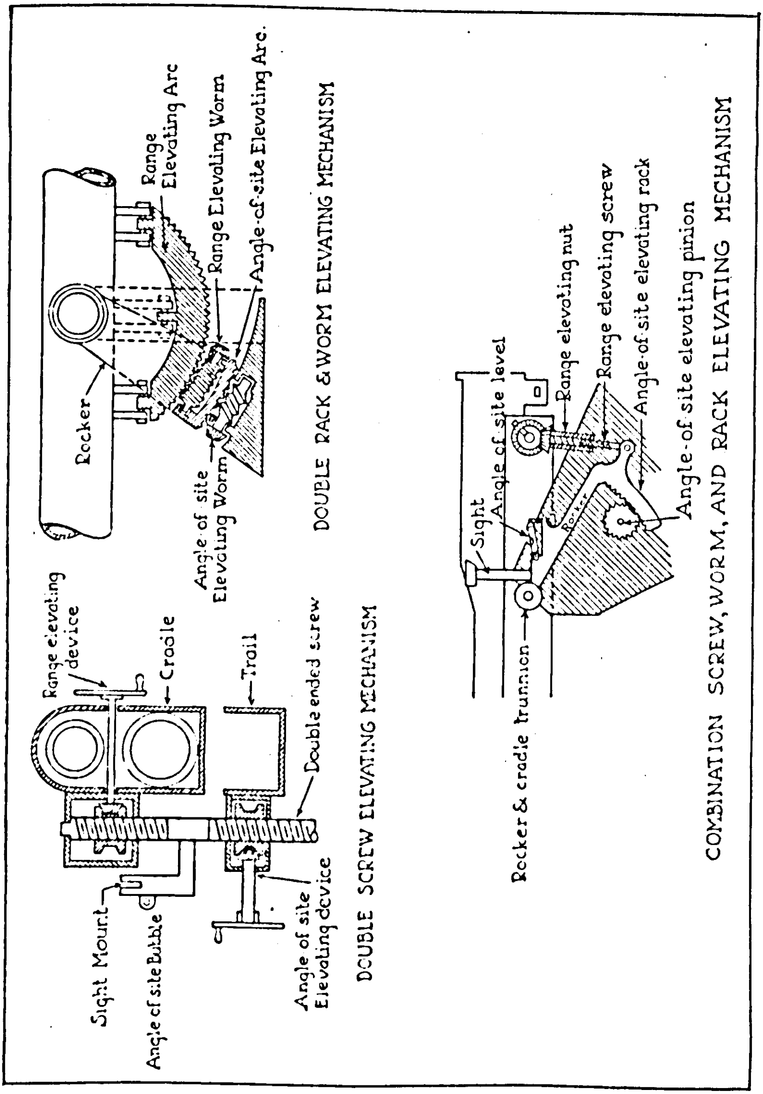


FIGURE 31.—Elevating mechanisms—gears.

double rack and pinion (or double rack and worm), a double screw, or a combination of rack and pinion and screw is required. On the other hand, for either the dependent or semi-independent systems, a single screw or a single rack and pinion with worm is used. Many of the heavier carriages and some of our newer carriages have two parallel racks and two pinions, one rack and pinion being on either side of the gun. These are not construed

as being double, since their function is to give greater strength rather than a double action.

b. The *rack and pinion* type consists of an arc, called the rack or segment, which moves or can be moved by a small spur gear, called the pinion. The rack may be attached to the tipping parts and the pinion to the fixed part of the carriage, or the reverse. Whenever a rack and pinion is used a worm and worm wheel must be placed in the gear train to make the system irreversible, that is, hold its position when the handwheel is released. In some cases, instead of using a rack and pinion with a worm in the gear train, a worm and a segment of a worm wheel are used. The rack and pinion has the advantages of great speed of operation, ruggedness, small friction losses, and suitability for movement over large angles of elevation. Examples of the rack and pinion are found on the 75-mm. howitzers, M1, M3, and M3A1, and on all the heavier carriages. An example of a double rack and worm are found on the 75-mm. gun, M1916 (American).

c. The screw type, consisting of a screw and nut between the tipping parts and a fixed part of the carriage, is actuated by a handwheel and suitable gears. Either the screw or the nut may be attached to the tipping parts. The screw type of mechanism has the advantages of lightness, irreversibility, and smoothness of action. An example of a double screw is found on the 75-mm. gun, M1917 (British), and an example of a combination screw, worm, and rack is found on the 75-mm. gun, M1897 (French).

Traversing Mechanisms

39. General.

a. A *traversing mechanism* (Fig. 32) is a device for making lateral changes, within the limits of the carriage design, in the direction of the axis of the bore. The moving parts may consist of only the gun and the upper parts of the carriage, or, in some cases, as in axle traverse, the parts may consist of the entire gun and carriage above the axle. Every carriage is so designed that the gun may be traversed only through that angle which does not cause instability when the piece is fired. When traversing, it is desired to obtain motion in a horizontal plane only. However, this condition can exist only when the plane upon which

traverse is made is horizontal. Either cant of the axle or slope of the ground between trail and wheels will introduce a change in elevation in addition to a change in direction. This change is small where the traverse is limited to a few degrees, but with larger traverse it assumes increasing importance.

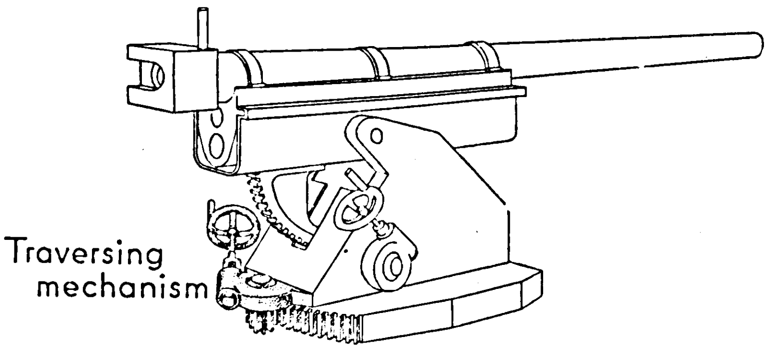


FIGURE 32.—Traversing mechanism.

b. For all except the heaviest weapons all-around traverse would be ideal. This, however, is impracticable without adding excessive weight and decreasing the flexibility of the piece. Therefore, pieces are given the widest traverse consistent with weight limitations imposed by the tactical requirements of the piece. With the light and medium guns, wide traverse is necessary to enable the gun to fire at rapidly moving targets and at targets widely dispersed, without shifting of the trails. With heavy guns, wide traverse is needed to permit covering a wide sector without trail shifting. With the lighter weapons the primary consideration is speed of traversing, whereas on the heavier guns it is primarily a consideration of the labor involved in making the shift.

c. Traversing mechanisms are of two types, *axle* and *pintle.*

40. Axle traverse (Fig 33).

a. In the axle-traverse type the upper part of the carriage, including the gun, is moved laterally along the axle, pivoting about the trail spade. This type of mechanism is applicable only to carriages with box trails.

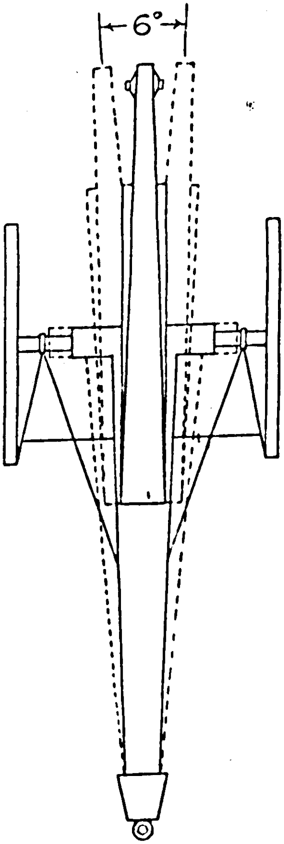


FIGURE 33.—Axle traverse.

b. The mechanism may consist of a threaded axle and traversing nut (Fig. 34) or of a separate traversing screw and nut (Fig. 35), together with the necessary gear train and handwheel. The traversing screw and nut make the system irreversible, so the only purpose of additional gears is to change the power ratio or the direction of the power applied at the handwheel. The threaded-axle type is simpler than the threaded-screw-and -nut type and is suitable only for the lighter carriages.

c. The advantages of axle traverse are:

(1) The direction of recoil is always along the trail, favoring lateral stability.

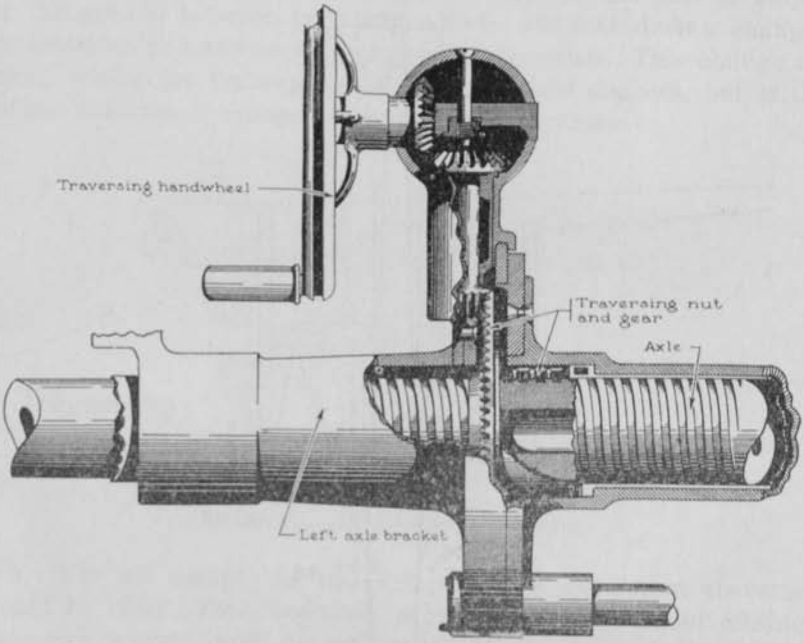


FIGURE 34.—Axle traverse, threaded axle and traversing nut.

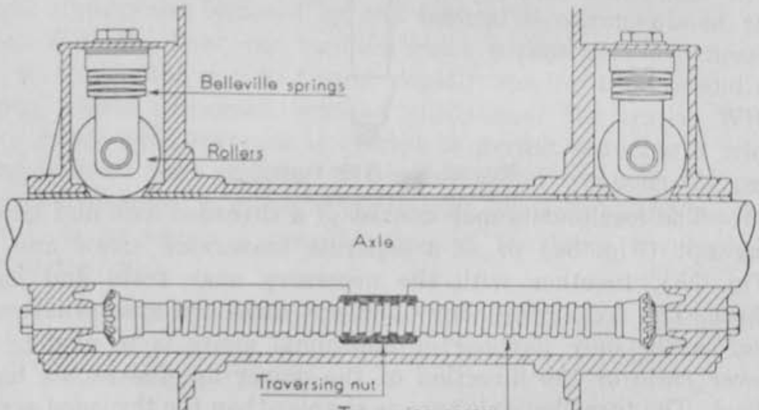


FIGURE 35.—Axle traverse, separate traversing screw and nut.

(2) The design is relatively simple and light.

d. The disadvantage of axle traverse is that the traverse on the carriage is limited by the length of the axle to a few degrees,

so that the trail ordinarily must be moved in changing targets or in following a rapidly moving target.

e. Examples of axle traverse with a threaded axle are found on the 75-mm. gun, M1897, and the 75-mm. howitzer, M1 (pack). An example of axle traverse with a separate traversing screw and nut is found on the 155-mm. howitzer, M1918.

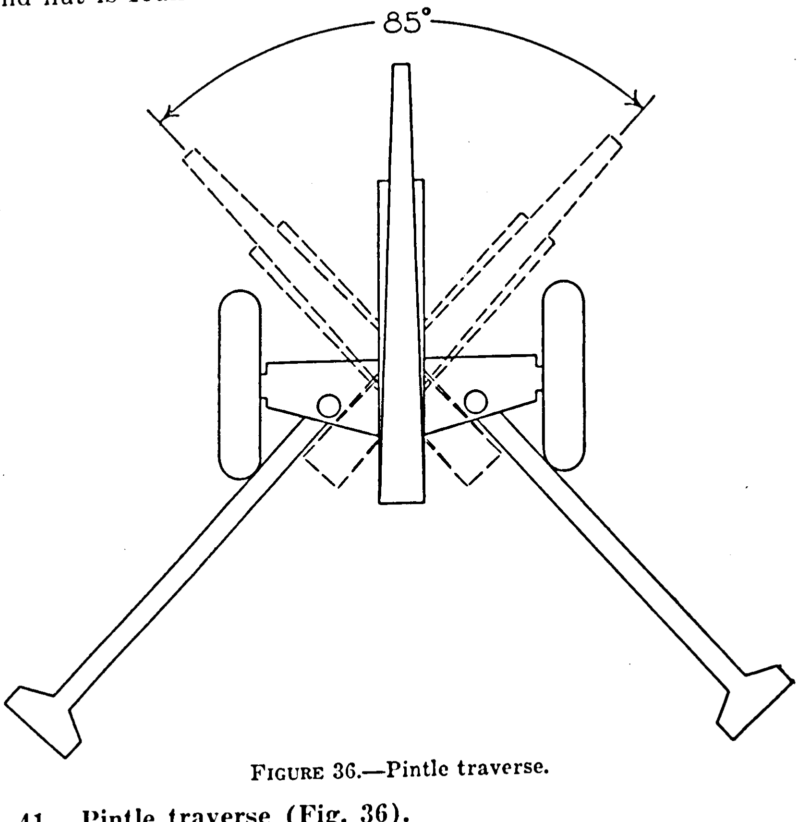


FIGURE 36.—Pintle traverse.

41. Pintle traverse (Fig. 36).

a. In the pintle-traverse type the gun is moved about a vertical pivot fixed on the axle or the under part of the carriage. It can be used with all types of trails, and it is the only type suitable for use with the split trail or with the pedestal carriage.

b. The mechanism consists of a handwheel and shaft which operates directly, or through a train of gears, a worm and rack or a pinion and rack (Fig. 37). As with the elevating mechanism,

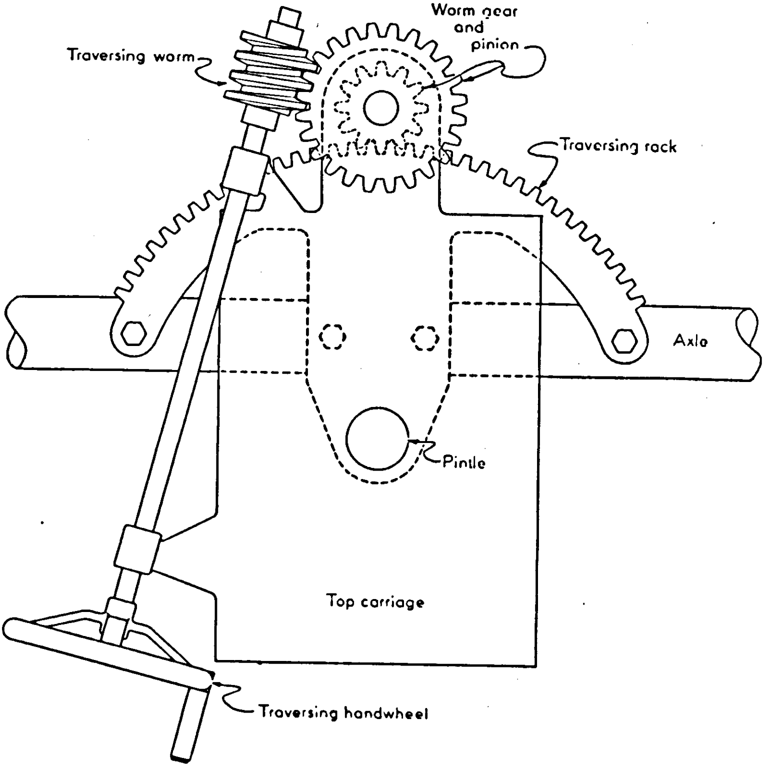


FIGURE 37.—Pintle traverse, construction.

some type of irreversible gear, such as a worm and wheel, must be included in the system to prevent movement of the gun when the handwheel is released. The handwheel may be attached to the traversing parts or to the fixed part of the carriage.

c. The advantage of pintle traverse is that it permits rapid and extensive traverse.

d. The disadvantages are:

(1) With the box trail, the lateral stability of the carriage is impaired, since the direction of recoil is not along the trail, except at the center of traverse.

(2) Because of the difficulty of sealing the mechanism it is subject to rapid wear.

e. Examples of pintle traverse are found on the 75-mm. guns, M1916 (American), M1917 (British), and M2, the 75-mm. howitzers, M3 and M3A1, and the 155-mm. gun, M1918.

Axles

42. Axles (Fig. 38).

a. An axle (Fig. 38) supports the weight of the carriage and gun, and has on its ends, directly or indirectly, spindles upon which the wheels are mounted. It may carry connections for the trails and brakes. Axles are of steel, either solid or tubular. Their design is influenced by the type of traverse employed on

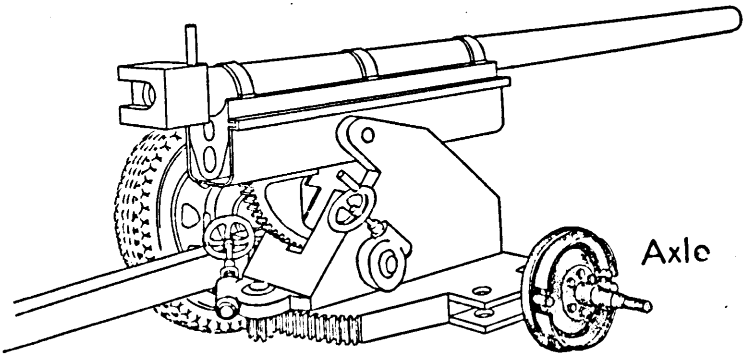


FIGURE 38.—Axle.

the carriage, the method of supporting the carriage weight, and the strategic speed for which the weapon is designed. The design of the axle differs with each type of carriage. For convenience in discussion, axles will be divided into the following classes: *Axle for axle traverse, axle for pintle traverse, axle for sprung carriage,* and *axle for rapid transport.*

b. For *axle traverse* (Fig. 39), the axle is cylindrical and has bearings on which the carriage, actuated by the traversing gear, slides or rolls in traversing. The axle, or a sleeve around the axle, may be threaded to receive the traversing gear, or the axle may be plain except for the attachment of a traversing nut to the axle. In either case, means are provided, usually by keys and keyways, to prevent the rotation of the axle on the carriage. The ends of the axle are either tapered to form a spindle, or they are formed so as to receive a *wheel carrier,* that is, a bracket

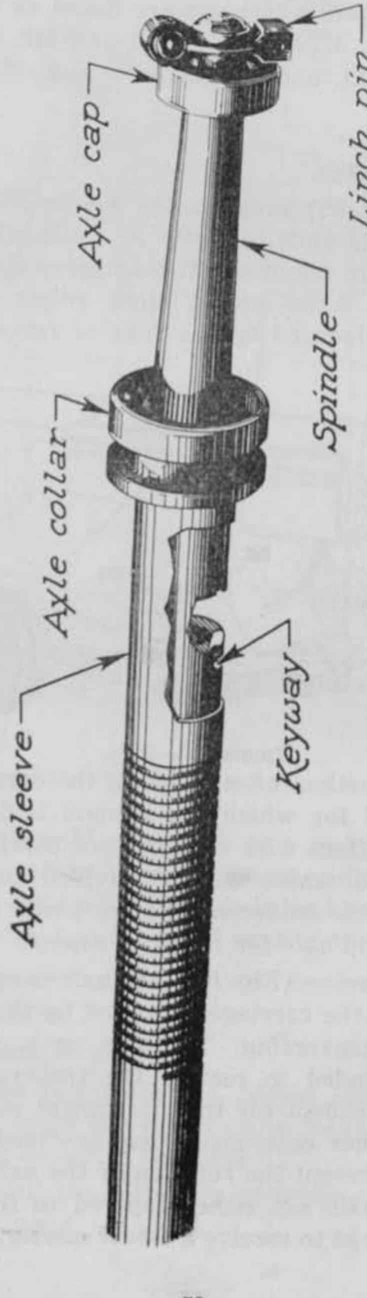


FIGURE 39.—Axle for axle traverse.

which attaches to the axle (or carriage) and carries a wheel spindle on its outer portion.

c. For *pintle traverse* (Fig. 40), the axle may be cylindrical, of built-up section or of I-section, and may be dropped in the center to lower the center of gravity. The wheel spindles may be separate pieces set in a housing which forms the center sec-

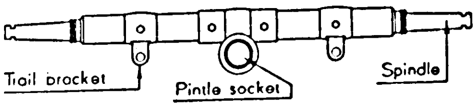


FIGURE 40.—Axle for pintle traverse.

tion of the axle, they may be an integral part of the axle, or they may be attached to wheel carriers which in turn are secured to the ends of the axle. The pintle socket is secured to the axle, as in the figure, or it may be secured to the bottom carriage which is fastened to the axle. The bottom carriage may be used to replace the axle by securing wheel carriers to the outer portions of the bottom carriage.

d. In some carriages, for transport, the weight is transmitted to the axle through springs; for firing, the weight rests directly on the axle. This type of carriage is known as a *sprung carriage.* Figure 41 represents one type of axle for a sprung carriage. The multiple-leaf spring is attached at the center to the bottom carriage and is suspended by detachable shackles underneath the axle. In traveling, the weight of the carriage is transmitted to

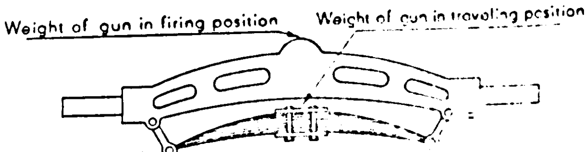


FIGURE 41.—Axle for a sprung carriage.

the axle through the spring, thus reducing road shocks. In the firing position, the spring is unshackled, permitting the bottom carriage to rest directly upon the arched central portion of the axle. A sprung carriage may also be obtained by using spring *wheel carriers* on the axle ends (Fig. 42). The wheel carrier is secured to the axle end, and the wheel spindle is assembled to the carrier, which is fitted with a coil spring between the upper and

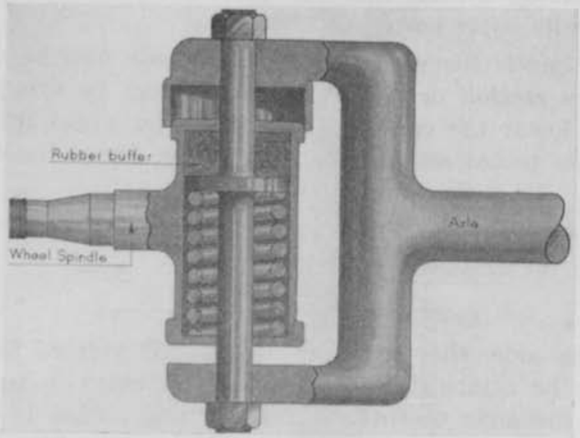


FIGURE 42.—Spring carrier.

lower portions. This type of construction is similar to the independent suspension used in automobile construction.

e. The use of plain wheel spindles and bearings restricts the speed of transport to a serious degree. With the use of pneumatic tires and antifriction bearings, the strategic speed of transport is limited only by that of the prime mover. *For rapid transport* many of our gun carriages have been modified by installing drop-hub assemblies, or wheel carriers, on the ends of the axle. These modifications carry wheel spindles upon which the pneumatic tires are mounted on antifriction bearings (Fig. 43). Because of the decrease in wheel size these carriers must lower the spindle height several inches from the axle in order to maintain a constant height of trunnions. The wheel carriers may be of the *springless* or the *spring* type. The former takes up road shock by means of the tires only, whereas the latter type assists the tires in reducing the road shock. In some cases the wheel carriers are so secured to the axle or carriage that when rotated the wheels are lifted from contact with the ground, the weight of the carriage during firing then being transmitted to the ground through a firing jack.

f. Examples of mechanisms discussed in this paragraph will be found as follows:

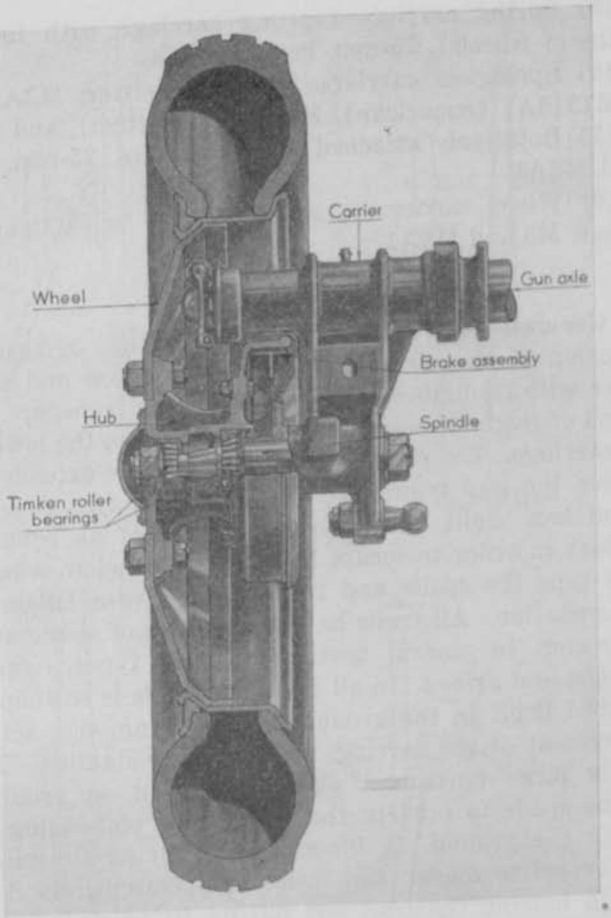


FIGURE 43.—Axle for rapid transport.

(1) Axle for axle traverse with threaded axle, 75-mm. gun, M1897 (French), and 75-mm. howitzer, M1.

(2) Axle for axle traverse with traversing nut secured to axle, 155-mm. howitzer, M1918.

(3) Axle for pintle traverse, 75-mm. guns, M1916 (American) and M1917 (British), 105-mm. howitzer, M1, and 155-mm. gun, M1918.

(4) Axle for sprung carriage with leaf spring, 155-mm. gun, M1918.

(5) Spring carriers (sprung carriage with independent springing of wheels), 75-mm. howitzer, M3.

(6) Springless carriers, 75-mm. howitzer, M3A1, 75-mm. guns, M1916A1 (American), M1917A1 (British), and M1897A4.

(7) Rotatively attached wheel carriers, 75-mm. howitzer, M3 and M3A1.

(8) Wheel carriers attached directly to carriage, 75-mm. howitzers, M3 and M3A1.

TRAILS

43. **General.**—The trail has two functions, to assist in the stabilization of the piece in the firing position and to connect the piece with its limber or prime mover for transport. The forward end of the trail is secured to the axle or to the lower portion of the carriage. The ends of box trails may be extended upward to receive the gun trunnions. Trails are of two general types, *split* and *box*. Split trails require the use of an *equalizer* or a *firing jack* in order to secure balanced suspension, whereas with the box type the spade and two wheels give a balanced three-point suspension. All trails have some form of spade at the rear or outer end. In general, these are of four types, *fixed, hinged, detachable*, and *driven*. In all cases the spade is so shaped that it will embed itself in the ground during firing, this action limiting movement of the carriage and insuring stability. A float, a relatively large horizontal plate or section, is usually placed above the spade to prevent the spade from embedding itself too deeply in the ground. A lunette for securing the piece to the limber or prime mover and, usually, a trail handspike for assisting in moving the trail end during firing are placed at the end of the trail.

44. **Split trails (Fig. 44 ①).**

a. A split trail is composed of two sections, each attached directly or indirectly to the axle or bottom carriage near the wheels. For transport, the sections are locked together at the rear end. For firing, they are separated as far as permitted by the wheels or trail stops. Usually, split trails are made of box section, built up of welded or riveted steel plates, and terminate in trail spades. For traveling, a lunette is assembled to one trail end, and a lock is fitted at the two ends to hold the trails

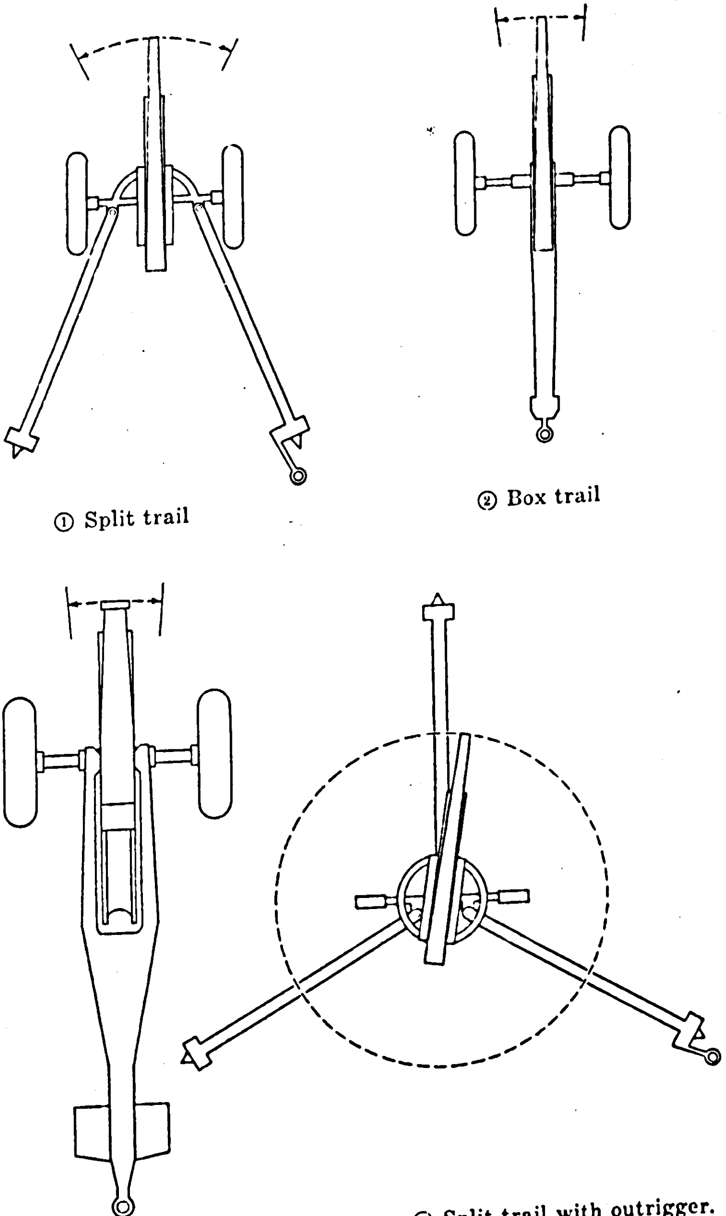
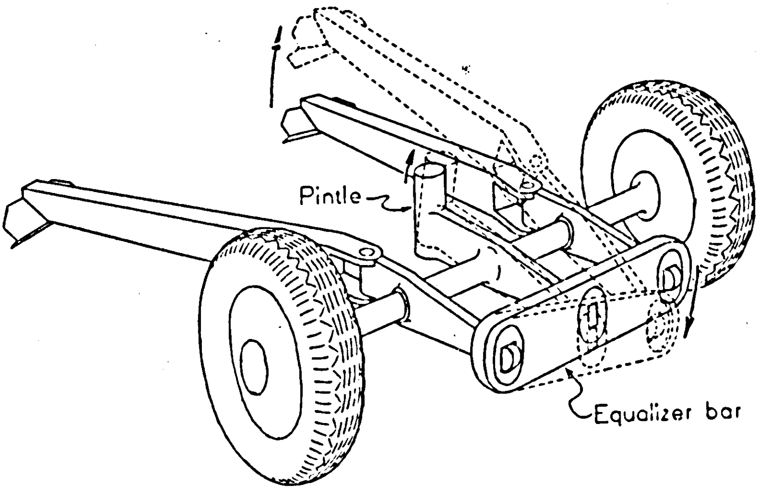


FIGURE 44.—Types of trails.

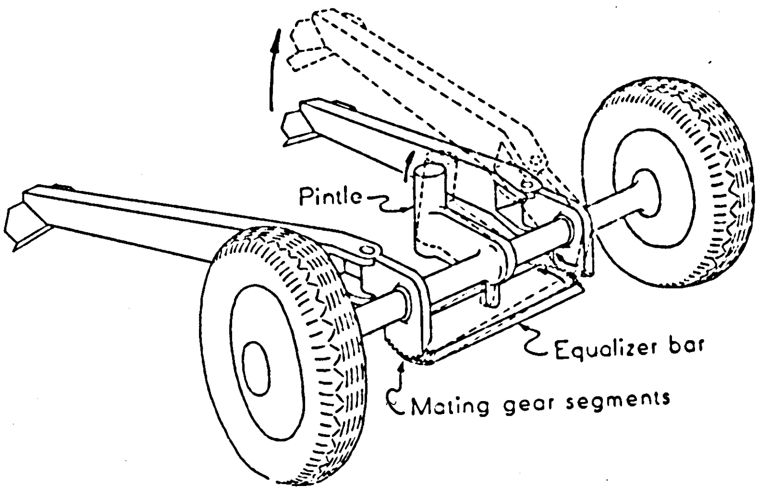
together. An *equalizer* or a *firing jack* is used to improve the stability of the carriage. These devices insure equal ground pressure of the two trail spades, regardless of the difference in level of the two spades or of the inclination of the axle. One modification of a split trail is known as *split trail with outriggers.*

b. An *equalizer* is a device which permits one trail to be raised or lowered with respect to the other without a corresponding movement of the carriage. When an equalizer is used, the front ends of the trails are attached to the ends of the equalizer arms by means of hinge pins (Fig. 45 ①), or they are rotatively attached to the axle and carry a gear segment on the front end which mates with a gear segment on the ends of the equalizer (Fig. 45 ②). In either case, the equalizer is attached to the axle and rotates in a plane parallel to the axle. In the first case, the inequalities of the terrain are offset by lowering or raising one trail and thus moving the other in the opposite direction. In the second case, a movement of one trail up or down moves that end of the equalizer through the gearing, thus moving the other end of the equalizer and the trail end in the opposite direction. There is a third type which has the trails secured to the carriage, the latter for firing resting on a raised knob (Fig. 41) on the axle. The advantages of an equalizer over a firing jack are simplicity, less weight, and rapidity of going into and out of action. The disadvantage lies in the difficulty of securing and maintaining a stable firing platform, as a result of the wear caused by road and firing shocks which are partially taken up through the equalizer. An example of the first type is found on the 105-mm. howitzer, M1, of the second on the 75-mm. gun, M1916 (American), and of the third on the 155-mm. gun, M1918.

c. A *firing jack* (Fig. 46) is a mechanical device which during firing provides a single support for that portion of the weight normally carried by the two wheels. This results in a three-point support, one point of contact being the firing jack and the other two points the spades of the trail. A firing jack can be used with either fixed or rotating wheel carriers. When folded in the traveling position, it is sometimes used as a cradle lock. To go into the firing position, the jack must be unfastened from its traveling lock and lowered. The carriage, if provided with fixed wheel carriers, is then lifted from the wheels. If the carriage is



① Equalizer bar.



② Equalizer bar and gear.

FIGURE 45.—Types of equalizers.

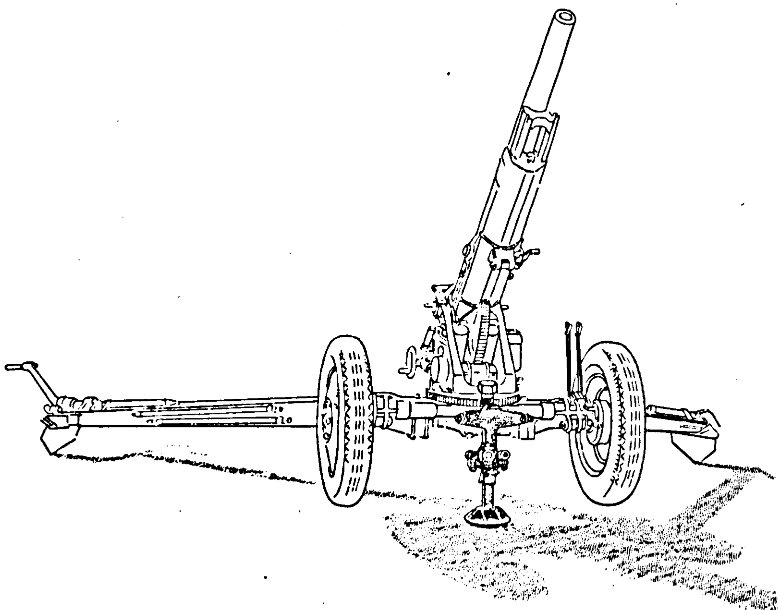


FIGURE 46.—Firing jack.

equipped with rotating wheel carriers, the carriers are rotated and the weight of the carriage is lowered onto the jack. The disadvantages of the firing jack over the equalizer are increased weight, complication, and additional time required to go into action. Its greatest advantage is in the greatly increased stability of the carriage under practically all conditions of terrain. Examples of firing jacks will be found on the 75-mm. howitzers, M3 and M3A1, and the 75-mm. gun, M2.

d. A *split trail with outriggers* (Fig. 44 ④) is a variation of the split trail consisting of two sections pivoted in the usual manner to a central pedestal and of one or two supplementary trails, called outriggers, which are attached to the pedestal for firing. The trails and outriggers are equally spaced about the central pedestal. The outriggers are normally transported by placing them on top of and securing them to the trail. The greatest advantage of this type of construction is the possible use of all-around traverse and high elevations. Increased weight, cumbersomeness, longer time required to occupy and move from position,

and increased time and cost of manufacture are disadvantages. No carriages of this type are used in the field artillery. Experimental carriages have been constructed and tested but have not been found satisfactory.

e. The advantages of split trails are wide traverse and high elevation on the carriage. Increased weight and complication in manufacture, maintenance, and operation are disadvantages. Most newer carriages, however, have split trails.

45. Box trails (Fig. 44 ②③).

a. A box trail is one which is composed of a single, rigid, built-up member. This may be simple *box, tubular,* or *modified box.* With all types of box trails the traverse on the carriage must be comparatively restricted in order to insure stability in firing. In most cases the front ends of the side plates are extended upward and provided with bearings to receive the gun trunnions, the side plates directly supporting the cradle and gun.

b. The simple *box trail* is generally composed of two side flasks, a top plate, and transverse transoms. This type of construction is simple, rugged, and comparatively light. An example will be found on the 75-mm. gun, M1897 (French).

c. The *tubular trail* is similar to the simple box type except that the main portion of the trail consists of a piece of tubular cross section. This construction has the same advantages as the simple box type. An example of this trail will be found on the 75-mm. gun, M1917 (British).

d. The *modified-box* type of trail (Fig. 44 ③) is a variation of the simple box trail which provides an opening between the flasks to permit recoil through it. This arrangement increases the permissable elevation on the carriage, but traverse is still restricted. This type of construction is somewhat heavier and more complicated in manufacture than other types of box trails. An example of this type of trail is found on the 155-mm. howitzer, M1918.

e. The greatest advantages of the box type of trail are simplicity, ease of manufacture and maintenance, ruggedness, and lightness. Its chief disadvantages are restricted elevation and restricted traverse.

46. Spades.

a. A *fixed spade* (Fig. 47) is one which is rigidly assembled to the trail end. It may be a forging, a casting, or a built-up construction. In general, the latter is the cheapest and lightest type. A fixed spade has the great advantage of simplicity and lightness. It has the disadvantages of being nonadjustable for various types of terrain and of decreasing the ground clearance

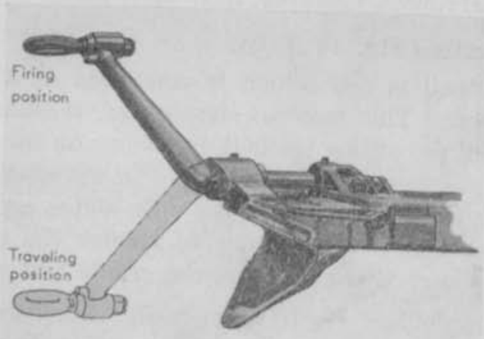


FIGURE 47.—Fixed spade with goose-neck lunette.

when in the traveling position. The latter disadvantage may be partially overcome by the use of a goose-neck or folding lunette, which raises the trail of the limbered piece several inches. Examples of fixed spades are found on the 75-mm. guns, M1897 (French), M1917 (British), and M2, and the 75-mm. howitzers, M1, M3, and M3A1.

b. A *detachable* spade is one which is detached from the trail end for traveling and assembled thereto for firing. A *movable (hinged) spade* is one which has one position for traveling and other positions for firing. In the first type a spade with the float attached is clamped to the trail end when the piece is placed in the firing position. In the second type, the spade is hinged to the end of the trail and can be adjusted to a position suitable for the type of ground. These constructions have the advantage of permitting the use of the proper angle of spade, or the proper type of spade, for the particular ground encountered. Disadvantages are increased weight, bulkiness, and additional time required to go into action. An example of the hinged type is found on the

155-mm. howitzer, M1918, of the detachable type on the 155-mm. gun, M1918.

c. A *driven spade* is one which, though assembled to the trail, requires that a member be forced into the ground for firing. In this type of construction the spade is normally secured to the trail and float by a ratchet device, which will permit the spade to be driven into the ground without motion of the float or trail, but which will prevent upward motion of the spade except when a latch is released. This type of spade has the advantages of giving great stability of the carriage even with short spades, and, usually, a reduction in the weight of the carriage. It has the disadvantages that additional time is required for emplacement, that emplacement is difficult on rocky ground, and that the spade is subject to breakage when being driven. An example of this type of spade will be found on the 75-mm. gun, M1916 (American).

WHEELS

47. **General.**—Wheels for artillery carriages are of three general types, *wood, cast-steel,* and *steel-disk.* Each type may be fitted with antifriction bearings, but the present tendency appears to be to make no change in the bearings of the wood wheels, and, if high speed is required, to install steel disk wheels containing antifriction bearings and equipped with pneumatic tires. The plain bearings used on the wood and cast-steel wheels restrict the carriages upon which they are used to an average speed of not over 8 miles per hour.

48. **Wooden wheels.**

a. The wooden parts of the artillery wheel are made of oak or hickory. The spokes, set in holes cut in the fellies or in spoke shoes riveted to the fellies, converge at the center of the wheel and are held securely in place by the hub box and ring. A bronze hub liner is fitted to the hub box and acts as a bearing for the wheel. In order to place the spokes in a better position to resist lateral thrust, the wheel is dished.

b. When a wheel is dished, the spokes, sustained by the encircling steel tire, yield mutual support to each other, and lateral thrust upon each spoke is converted into a compression strain, which wood is better able to resist. In order to allow the weight of the

carriage to be carried on a vertical or nearly vertical spoke at all times, it is necessary to give a slight downward inclination to the wheel spindle. The downward inclination of the axle together with the dish of the wheel produces a tendency for the wheel to roll outward. This tendency is corrected by slightly inclining the axle ends toward the direction of travel in order to produce toe-in of the wheels and cause the wheels to move in a straight-ahead direction.

c. Wood wheels in use at the present time vary in diameter from 52 to 56 inches for 75-mm. guns. For use with horse-drawn artillery they are steel tired.

d. Examples of wood wheels will be found on the unmodified 75-mm. guns, M1897 (French), M1916 (American), and M1917 (British), and the 75-mm. howitzer, M1 (pack).

49. Cast-steel wheels.

a. This wheel is an assembly of a cast-steel body called a wheel center with one or more solid rubber tires. When two tires are mounted on the rim, a tire-separator ring of forged steel is placed between them. The hub of the wheel center is fitted with a hub liner of bronze (except the modified 155-mm. gun, M1918). The hub is sealed by means of washers and a hub cap to prevent the entrance of dirt or loss of lubricant.

b. Cast-steel wheels are used only on heavy gun carriages, where the greatest strength is needed. The resulting loss in resiliency must be overcome by the use of hard rubber tires and, perhaps, springing of the load. Cast-steel wheels with solid rubber tires are very heavy; one for the 155-mm. gun, M1918, weighs 985 pounds. This wheel (155-mm. gun) has been modified for high speed by the use of antifriction bearings. The wheels may vary in diameter from 46 to 66 inches and in the treads up to 12 inches.

50. Steel disk wheels.

a. This wheel is a standard commercial automobile wheel of the disk type, made of pressed steel and secured to the hub by bevel-faced nuts. The wheel mounts a standard pneumatic truck tire. The tubes are of the puncture-sealing type, partially bullet-sealing. When a puncture or blowout occurs, the entire wheel

assembly is removed from the hub and a spare wheel is installed. The hub is mounted on antifriction bearings, usually of the tapered-roller type.

b. There are no dual mountings on present carriages, the tire size being large enough to withstand the loads. Experiments have been conducted using, in a dual mounting, an outer tire of a smaller size than the inner tire, so that flotation may be increased in soft ground.

c. In general, the resistance to traction is reduced by the use of pneumatic tires and antifriction bearings. However, when the carriage is being pulled on an incline the weight of the carriage is the major factor. All light and medium pieces may be fired directly from the pneumatic tires without undue loss in stability. Also, tests seem to indicate that, if the tube assembly is securely fastened in the traveling position, the pneumatic tires sufficiently reduce the road shock without the necessity of using spring wheel carriers. The speed of the piece is limited, from a materiel standpoint, to that of the prime mover. From a safety standpoint the speed is limited by the braking distance of the piece and prime mover.

d. Types of steel disk wheels are found on all modified war-time carriages and also on all of the newer carriages except the 75-mm. howitzer, M1 (pack), and the 105-mm. howitzer, M1.

BRAKES

51. **General.**—All artillery mobile carriages are equipped with road brakes of either the *tire* or *drum* type. These brakes may be operated *mechanically, electrically,* or by *air.* This operation may be *individual* to each brake, *simultaneous* to all braked wheels, or a *combination* in which simultaneous operation is used for traveling and individual operation for hand movement and for firing. On some carriages the road brake serves also as a firing brake, while on others an additional means of operation is necessary for using the road brake as a firing brake. This latter is true of electric or air brakes operated from a prime mover. When the prime mover is disconnected the brakes will not function except by the mechanical means assembled to the carriage.

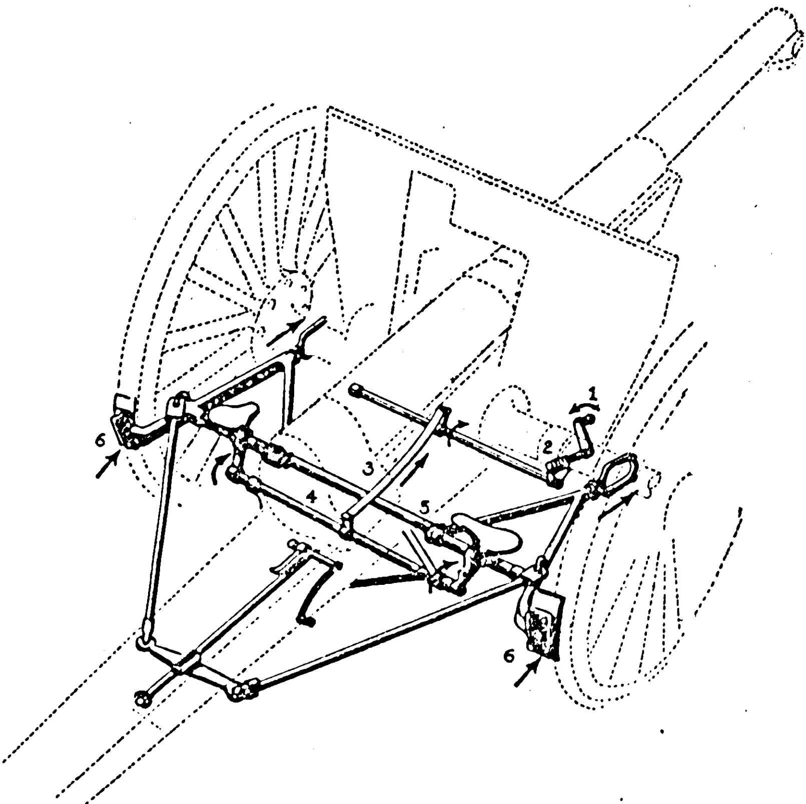


FIGURE 48.—Tire brake.

52. Types of brakes.

a. A *tire brake* (Fig. 48) is one in which brake shoes, actuated by appropriate mechanism, are brought against the tires of the wheels to resist their movement. A brake shaft carries two shoes, one in contact with each tire. A mechanical linkage brings the brake shoes tightly against the tire or releases them. This type of brake is simple, but it requires steel-tired wheels, is subject to malfunctioning because the linkage and shoes are open to dirt and moisture, and does not give a uniform braking effort. An example of this mechanism is found on the 75-mm. gun, M1897 (French).

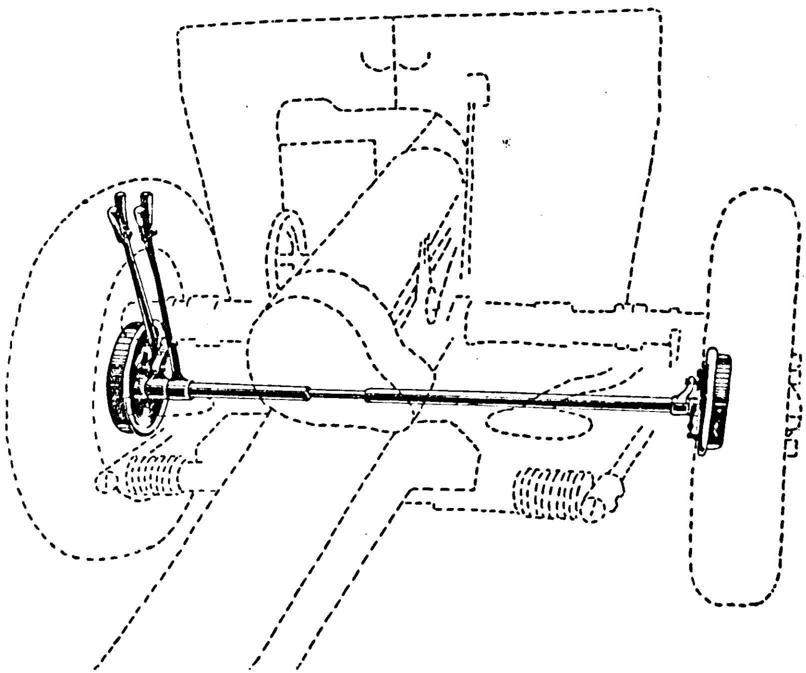


FIGURE 49.—Drum brakes.

b. A *drum brake* (Fig. 49) is one in which a flexible steel band, lined or unlined, or movable steel shoes formed in an arc, are forced against a brake drum. Drum brakes are of two general types, *external contracting* and *internal expanding*. In the external contracting type, the flexible steel brake band, unlined or lined with friction material, is caused to contract about the brake drum which is secured to the wheel. In the internal expanding type, lined brake shoes are mounted inside of the brake drum and, through appropriate linkage, are caused to expand against the interior of the drum. In general, band brakes are of standard commercial automobile type.

53. Operation of brakes.

a. Mechanical brakes depend upon a hand- or foot-operated mechanical linkage for their operation. Usually, for safety and for operation as firing brakes, all carriage brakes have means for mechanical operation in addition to any other means used. The linkage used is similar to types used in automobile construction.

b. Electrical brakes are those which function by means of electric current actuating an electro-magnet. This type of operating mechanism is used on heavy carriages. One of the types used is the Warner brake, built for and used by the automobile industry.

c. Air brakes are those which are actuated or boosted by means of air pressure. This type of operating mechanism is used on medium and heavy carriages. The type usually used is that known as the Westinghouse Air Brake.

SHIELDS

54. General.—Shields are provided on most light and medium artillery carriages for the protection of the cannoneers. The shield is constructed of thin armor plate sufficiently strong to resist penetration by a caliber .30 ball cartridge at 100 feet. Shields are not usually provided for heavy artillery. Shields, according to type, may be classed as, *hinged, one-piece,* and *demountable.*

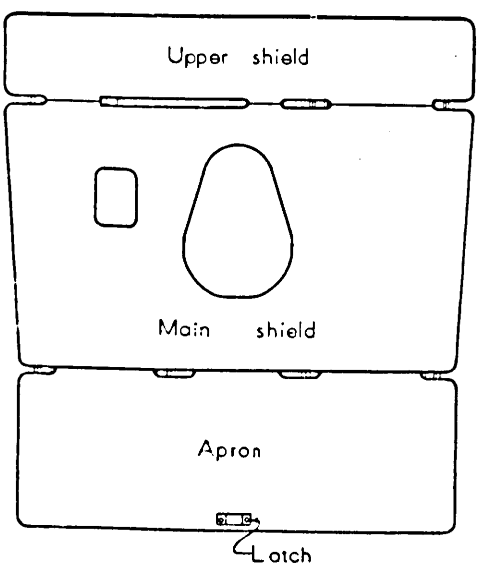


FIGURE 50.—Hinged-type shield.

55. Types of shields.

a. A *hinged shield* (Fig. 50) is one which consists of a main shield, fixed to the carriage, an apron(s) below it, which folds

upward for transport, and sometimes an upper shield above it, which folds to the rear for transport. The main shield is fixed to the axle or lower part of the carriage by means of supporting brackets. The upper shield is hinged to the main shield so that it may be lowered for traveling or when using aiming points in front of the battery. The apron is hinged to the lower portion of the main shield so that for traveling it may be raised and secured by a latch or a pawl. The apron may be split into two parts with a space for carriage clearance between the parts.

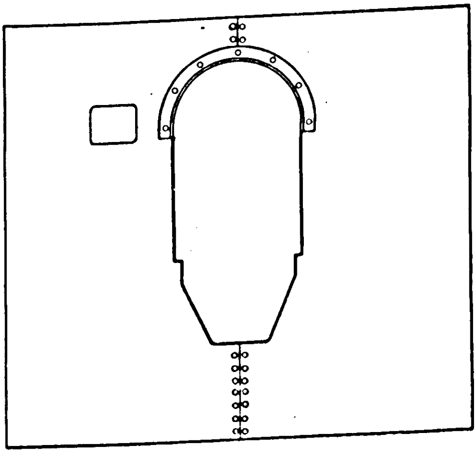


FIGURE 51.—One-piece shield.

b. A *one-piece shield* (Fig. 51) usually consists of a right and a left member riveted together at the center to form one rigid piece. The shield is usually bolted to brackets secured to the trail flasks and the axle or brake shafts. To increase the rigidity of the shield, angle iron stiffeners are used. A shield of this type will be found on the 155-mm. howitzer, M1918.

c. A *demountable shield* (Fig. 52) is one which is assembled to the carriage for firing and is removed from the carriage for traveling. This type of shield is usually constructed in two halves, each half folding on hinges for travel. The tube projects through the opening between the two halves of the shield. In the firing position, the halves are assembled to the carriage by slots which fit over buttons on the carriage and by a chain around each wheel. A lever, when moved from a vertical position to a posi-

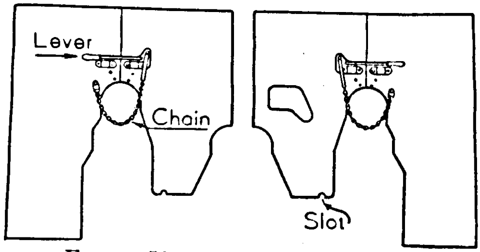


FIGURE 52.—Demountable shield.

tion in contact with the shield tightens the chain and at the same time serves to lock the two folding parts in the open position. This type of shield is used on some of the newer materiel such as the 75-mm. howitzers, M3 and M3A1.

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